Flight Safety Foundation

Safety Benefits Of The Wide Area Augmentation System During Instrument Approaches

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Revision 1

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Executive Summary

The key benefit associated with Wide Area Augmentation System (WAAS) is that it provides accurate and reliable navigation information in three dimensions. This means that the pilot can receive accurate information on their relative position in the traditional two-dimensional horizontal plane of latitude and longitude as well as accurate information about their position in the vertical plane or altitude.

The focus of this study is the measurement in risk reduction that can be anticipated with the implementation of WAAS within the National Airspace System (NAS). Specifically, this study evaluates the anticipated reduction in accidents and loss of life through the future addition of the precision approach capability provided by WAAS to airports that currently have runways with non-precision approaches. This evaluation was limited to this very specific focus because it was a benefit that could be quantified and described.

Based on these analyses, it was found 141 accidents could be prevented over a 20-year period and over 250 lives saved through the introduction of the Wind Area Augmentation System. This is a conservative estimate.

The safety improvements cited in this study will be greater if the overall growth rate for aviation exceeds the growth rate of 2% used in this analysis. If the growth rate averages 3% per year for the period of 2001 to 2020, the total number of accidents prevented will increase to approximately 175 and the number of lives saved will increase to 315. Conversely, if the growth rate only averages 1% per year during this time period, the accidents and deaths prevented will total 114 and 206 respectively.

Other benefits provided by WAAS are also reviewed and described. WAAS based approaches will allow pilots to establish and maintain stabilized approaches, providing obstacle clearance at night when terrain features are not visible and the use during marginal visual conditions (usually considered as three to five miles visibility). These benefits would most likely be most pronounced among single-pilot flight operations. Moving map displays will help pilots maintain their situational awareness, a key component to safe flight, especially in instrument conditions. It will also encourage point-to-point navigation reducing fuel use and improving air traffic control routing flexibility.

Airports that currently do not have any instrument approach capability will be able to add precision approach capability assuming the airport is not surrounded by obstructions that make instrument approaches infeasible. This benefit would also be applicable to heliports at hospitals, and other location. This should improve the utility of these airports and heliports, reduce capacity demands on larger airports, and improve safety because pilots will be able to fly instrument approaches to airports or heliports that are more convenient.

Safety Benefits Of The Wide Area Augmentation System During Instrument Approaches

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I) Introduction

The United States Department of Defense (DOD) began a research and development plan in the early 1970s to develop an integrated navigation and position determination system based on information transmitted from series of geostationary satellites. This system is often referred to as the Global Positioning System or GPS. The first operational satellite was deployed in 1989. The benefit of GPS is that it provides precise navigation signals anywhere satellite coverage is available.

The Federal Aviation Administration (FAA) recognized that the type of guidance available from the GPS system would have large potential benefits for the civilian aviation community. According to the FAA, these benefits included precise three-dimensional navigation (altitude guidance as well as lateral guidance), reduced separation standards for more efficient use of airspace, precision approach capability at all runways, lower avionics costs, reduced training costs, and significant cost savings due to the eventual reduction of ground-based navigation systems. In addition to the economic benefits, there are potential safety benefits as well.

The FAA has been developing a civilian aviation navigation system based on the GPS system for the last decade. A key component of the FAA's system is known as the Wide Area Augmentation System (WAAS). The goal of WAAS is to provide an accurate and reliable navigation signal for civilian aviation to support all phases of flight, including precision approaches to landing facilities to Category 1 precision approach standards (200 foot above ground level and ½ mile visibility).[1]

A) Background

WAAS Description

The key benefit associated with WAAS is that it provides accurate and reliable navigation information in three dimensions. This means that the pilot can receive accurate information on their relative position in the traditional two-dimensional horizontal plane of latitude and longitude as well as accurate information about their position in the vertical plane or altitude. This information, as provided by the WAAS augmentation to GPS, can provide accuracy in the neighborhood of 7 meters (roughly 23 feet). The information provided by WAAS can therefore provide pilots with precise vertical and horizontal guidance.

The type of information that will be available to pilots from WAAS will include precise enroute navigation information, actual ground speed, height above terrain, and precision approach guidance. WAAS will also support moving map displays in the cockpit that highlight the aircraft's position relative to fixed features such as terrain, navigation routes, and runways. All of these benefits, plus others not mentioned, will prove helpful to pilots and likely improve the safety of all flight operations.

Research Goals

While many of the benefits of GPS, and specifically WAAS, have potential positive economic components, there are also many potential safety benefits that can be expected from the introduction of the enhanced navigation capability provided by WAAS. The focus of this study is the measurement in risk reduction that can be anticipated with the implementation of WAAS within the National Airspace System (NAS). Specifically, this study evaluates the anticipated reduction in accidents and loss of life through the addition of the precision approach capability provided by WAAS to airports that currently

[1] This information was obtained from the FAA's Satellite Navigation Website located at: http://gps.faa.gov/Basics/GPS_benefits/gps_benefits.htm

have runways with non-precision approaches (see description below). The evaluation is limited to the National Airspace System (NAS) and will rely on retrospective safety information from the last 18 years.

Objectives: There are two main objectives associated with this study. They are:

1) Quantify the safety benefits associated with implementation of the WAAS in the NAS.
2) Develop graphical depictions of the benefits of WAAS (as measured by losses prevented).

Research Questions: The basic research questions to be answered by this project are:

1) Will WAAS implementation reduce the risk of accidents?
2) How much safety improvement will result from WAAS implementation?

Differences in Approach Types

The basic tenet underlying this study is that precision approaches provide additional safety benefits to pilots when compared to non-precision approaches. To better understand this assumption, some background on these two approach types might prove helpful along with a short description on the concept of a stabilized approach.

The Flight Safety Foundation provides the following definition for precision and non-precision approaches as well as what constitutes a stabilized approach.

> **Precision Approach:** An instrument approach with lateral and vertical guidance from the final approach point (FAP) to the runway touchdown zone, with system accuracy, integrity and obstacle clearance (including go-around) guaranteed until the descent limit (decision altitude or decision height) is reached.
>
> **Non-precision Approach:** An instrument approach with lateral guidance only from the final approach fix (FAF) to the runway environment. Descent limit is the minimum descent altitude (MDA), and obstacle clearance (including go-around) is guaranteed if the approach is discontinued no farther that the missed-approach point (MAP).
>
> **Stabilized Approach:** An approach procedure along the extended runway centerline with a constant, in-flight verifiable descent gradient from the final approach altitude to the runway touchdown zone. ILS (instrument landing system) procedures are inherently stabilized approach procedures (except in the rare case of an off set localizer).[2] More information on stabilized approaches is provided in Appendix 2.

Generally speaking, in the United States, precision approach guidance is provided by a system called the instrument landing system or ILS. The ILS system includes two transmitters located near the end of a runway that is dedicated to providing the electronic signal for both vertical and lateral guidance for aircraft approaching that runway. The ILS system is usually supplemented with additional guidance in the form of specialized approach lighting to the runway. The most common ILS approach is a Category 1 precision instrument approach which provides for an approach to a height above touchdown of not less than 200 feet and with runway visual range (RVR) of not less than 2,400 feet (1/2 mile). Lower approach minimums can be achieved with ILS systems but this requires special certification for the pilots, the aircraft and the ILS equipment and is only justified in areas where very low ceilings or visibility is common. Other types of precision approaches include precision approach radar (PAR) which is usually

[2] Enders et al, *Airport Safety: A Study of Accidents and Available Approach-and-Landing Aids*, Flight Safety Foundation Digest, Vol. 15, No 3., March 1996

limited to military facilities and microwave landing systems (MLS) which are uncommon. As might be expected, the installation and maintenance of precision approach facilities are fairly complex and costly.

One of the key benefits of the precision approach is that it ensures obstacle clearance if the vertical and horizontal guidance is adhered to. It also aids the pilot in establishing and maintaining a stabilized approach; a basic tenet to safe landing.

Non-precision approaches do not provide electronic vertical guidance like that of a precision approach. It is also fairly common for the lateral guidance to be less precise that that provided by an ILS system. A broad variety of navigation transmitters can be used to provide the lateral guidance to a specific runway end for a non-precision approach. These include very high frequency omni directional radio signals (VOR, a standard enroute navigation aid), non-direction beacons (another general navigation aid), ILS signals without the vertical guidance (often termed a localizer approach) and a variety of other less common navigation devices including approaches using current GPS signals.

The differences between the precision approach and non-precision approach become more apparent when the procedures used to fly the different approaches are considered. (It should be noted that there are a great many variations to the general procedures described here.)

During an ILS approach, the pilot receives both vertical and lateral guidance that leads them to the centerline of the touchdown zone of the runway. Usually, this information is displayed in such a fashion that the pilot can determine if they are maintaining the proper lateral and vertical course to arrive at the touchdown zone. If the pilot follows this guidance accurately, they will reach the decision height (DH) near the end of the runway. If the visibility is such that the pilot cannot see to land, a missed approach will be executed. If the pilot follows the ILS guidance properly, they will end up at the approach end of the runway. Ideally, the pilot will have flown a stabilized approach and will be in the proper position and configuration to land.

During a non-precision approach, a pilot must ensure that he or she does not descend below the minimum descent altitude (MDA), an altitude that is usually determined by referring to the barometric altimeter. Lateral course guidance to the runway, or its environment, is provided by the navigation signal the approach is based upon. In a VOR approach, the VOR receiver is used to provide input to a course deviation indicator (there are many different ways to display this information). For an NDB approach, guidance may be in the form of an automatic direction finder (ADF) indicator. For a localizer only approach, the ILS indicator may be used or the signal may be transferred to another course indicator.

The difficulties associated with a non-precision approach are many. The pilot must maintain a specified altitude (MDA) until the runway is seen. If the runway isn't seen within a specified time (or until another navigation fix is passed) the pilot must execute a missed approach. If the pilot sees the runway, he or she may not be in a good position to land since the lateral guidance of the approach is less precise than that of a precision approach, or the pilot may be too high to conduct a stabilized descent. Additionally, the non-precision approach requires more work for the pilot since additional information must be monitored and assimilated. For these reasons, flying a non-precision approach can be a challenge for the most experienced pilot. Among inexperienced pilots, or pilots who are fatigued, the workload associated with a non-precision approach can be very high with an increase in risk.

Past Research and Accidents
There is a significant body of research and accident experience demonstrating that having precise information on vertical guidance during approach to landing significantly reduces the risk of an accident. The Flight Safety Foundation found that commercial aircraft operators worldwide were five-fold more likely to experience an accident during a non-precision approach as were their contemporaries who were

conducting Category 1 precision approaches.[3] A number of other factors were also evaluated in this study in recognition that multiple factors influence the safe conduct of any flight including the successful completion of instrument approaches.[4] Even when these other factors were considered, ~~the~~ same overall pattern of greater risk being associated with the non-precision approach remained.

The benefits of the precision approach are further emphasized by another study conducted by the Flight Safety Foundation in 1998.[5] In this study, it was found that fully three quarters of all accidents involving turbo-prop or turbo-jet airplanes on approach occurred without the guidance provided by precision approaches.

There have been a number of high profile accidents involving the air carrier airplanes in which poor pilot procedures while flying a non-precision instrument approach were a significant factor. One of the most notable was that of a U.S. Air Force transport CT-43A (Boeing 737-200) carrying Secretary of Commerce Ron Brown while on approach to Cilipi Airport, Dubrovnik, Croatia.

On April 3, 1976 the crew of the CT-43A were attempting to fly a non-precision instrument approach (a non-directional beacon or NDB) in instrument meteorological conditions (IMC) to Runway 12 at the Cilipi Airport. While on approach the aircraft collided with a 2,300 ft high mountain. All six crew members and 29 passengers aboard were killed in the accident. Although a number of factors were involved, the USAF Accident Investigation Board concluded "the accident was caused by a failure of command, air crew error and improperly designed approach procedure." With respect to "air crew error", reconstruction of the final approach profile indicates that the aircraft tracked a course of 110 degrees inbound to the NDB rather than 119 degrees.[6] This resulted in the aircraft flying left of course and impacting high terrain. If a precision approach capability had been operational at the time, the accident may not have occurred.

Another tragic accident that may not have occurred if an operational precision instrument approach been present was the controlled flight into terrain (CFIT) accident involving Korean Air Flight 801, a Boeing 747-300 that crashed during final approach to Agana Airport, Guam on August 6, 1997. In this accident, the flight crew had been expecting a precision approach (an ILS) to the airport in night IMC conditions. Air traffic control informed the flight crew, however, that the glide slope was out of service and directed them to fly a localizer only non-precision approach. Analysis of the cockpit voice recorder (CVR) indicates there was confusion about the glide slope status among the flight crew but the crew did set the cockpit instrumentation correctly for the non-precision localizer only approach. The crew performed the approach but did not initiate a missed approach quickly enough when they had determined that the runway was not in sight. The NTSB determined that the "probable cause of the Korean Air 801 accident was the captain's failure to adequately brief and execute the non-precision approach and first officer's and flight engineer's failure to effectively monitor and cross-check the captain's execution of the approach." The airplane impacted Nimitz Hill, which is three miles southwest of the airport. A total of 228 of the 254 persons aboard the flight were killed.[7]

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[3] Enders et al, ibid

[4] These other study factors included pilot experience, type of airplane, environmental conditions, presence of high terrain and presence of radar to name just a few.

[5] Khatwa R, Helmreich RL, *Analysis of Critical Factors During Approach and Landing In Accidents and Normal Flight*, Flight Safety Foundation Digest, Vol. 17, No 11-12, November-December 1998. pp. 47

[6] *Dubrovnik-bound Flight Crew's Improperly Flown Non-precision Instrument Approach Results in Controlled-flight-into-terrain Accident*, Flight Safety Foundation Digest Vol. 15 No.7/8 July- Aug 1996 pp.1

[7] *Controlled Flight Into Terrain, Korean Air Flight 801, Boeing 747-300, HL7468*, Flight Safety Digest, Vol. 19 No. 5-7, May-July 2000, pp. 9

Benefits of Precision Approach Aids in Instrument and Visual Meteorological Conditions
While the benefits associated with precision approaches are primarily associated with instrument flight conditions, there are significant benefits associated with the use of precision approach guidance in other situations. For example, the guidance from a precision approach can be used to provide additional backup guidance for landing in either day or night visual meteorological conditions. This can assist the crew in obtaining and maintaining a stabilized flight profile. It can also assist if there are significant cross winds or turbulence since the pilot will have a solid reference to what the stabilized flight path should be.

The benefits from the introduction of WAAS must also be considered for those runways that currently do not have instrument approaches. While air carriers in the U.S. do not fly to airports that do not have instrument approaches, a large segment of the general aviation fleet does. In those cases, the benefits of WAAS-based precision approaches are large. These include the addition of instrument approach capability to airports that have been limited to operations in good weather (VMC conditions) that would improve access the airports. This improved instrument capacity may also reduce pressure on airports that currently service general aviation aircraft in instrument metrological conditions. The non-instrument advantages described in the paragraph above would also apply.

Finally, WAAS should prove to be of great benefit to the helicopter community. Currently the vast majority of heliports in the United States do not have any instrument approach capability. The introduction of WAAS will provide these heliports with a cost effective precision approach capability, something not available today. Such capability would prove beneficial to the over 500 hospital heliports nationwide that receive patients by helicopter or to the numerous heliports operated by municipalities and businesses. It might also spark resurgence in the use of helicopters to transport passengers from city center to city center in busy areas such as the northeastern United States.

WAAS Characteristics
The FAA plans to have WAAS precision approach capability fully implemented by Fiscal Year (FY) 2009 although initial WAAS services will soon be available. The goal of the WAAS program is to provide precision approach capability for runways throughout the continental US, portions of Alaska, Hawaii and the Caribbean. There are three levels of instrument approach services to be provided by WAAS.

The first level of service will be basic lateral navigation (LNAV) capability. This capability will provide non-precision approach capability with approach minimums of 600 feet above ground (MDA) and ½ mile visibility (for smaller Category A and B airplanes) and 1-mile visibility for larger airplanes (Category C and D). This represents an incremental development step that will be superceded by WAAS based precision approaches as described below.

The second level capability, called LNAV/VNAV (for lateral and vertical navigation) will reduce the landing minimums and provide precision vertical guidance. The minimums for this level of service will be 400 foot above ground decision height (above ground) and ½ mile visibility for Category A,B and C aircraft. The visibility requirements will be 1-mile for Category D aircraft. The LNAV/VNAV capability will represent a precision approach capability.

The final level of service, called GLS (Global Navigation Satellite System Landing System) will provide the lowest minimums available with WAAS. The minimums associated with GLS will be 200 feet above ground decision height and ½ mile visibility for all aircraft. This is equivalent to the current Category 1 approach standard for ILS approaches.

Currently there are 5,069 public use airports in the United States. At these airports, there are approximately 561 ILS approaches and 1,500 non-precision approaches (it should be noted that an airpo can have an instrument approach to more than one runway). Obviously, there are a large number of airports that could benefit from the addition of precision approach capability.

WAAS Implementation Schedule

The FAA plans to have initial LNAV/VNAV capability available in FY 04 with full LNAV/VNAV function available by the beginning of FY 08. GLS capability is scheduled to be introduced at the beginning of FY 08 and fully available by the middle of FY 09. It should be recognized, however, that having the WAAS capability available does not guarantee that precision instrument approaches will be available for runways that have no approaches now or for those runways that have non-precision approaches. The FAA must also ensure that the new WAAS approach is safe to fly and meets applicable standards (as defined in the FAA Order 8260.3B, U.S. Standards for Terminal Instrument Procedures, often referred to as TERPS). This will require obstacle clearance review and the installation of approach lighting. The FAA plans to have all runways at airports serving air carrier traffic[8] approved for WAAS precision approaches by 2006. Those runways that do not serve air carrier aircraft but have runways longer than 5,000 feet should be available for WAAS approaches by 2010 and all other runways (as deemed appropriate) should be approved for WAAS based approaches by the end of 2015.[9]

Another factor that must be considered is the how quickly aircraft will be equipped to use the WAAS signal for instrument approaches. Currently, very sophisticated GPS receivers for aviation use including moving map displays are available for $3,000.[10] The FAA projects that roughly 80% of the civil fleet in the United States will be equipped with at least one WAAS capable receiver, and that 50% of the fleet will have a dual installation, by 2010.[11]

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[8] FAR part 139 approved airports.
[9] Presentation given by D. Pate, Manager Flight Procedure Standards Branch, Federal Aviation Administration at the EUROCONTROL RNAV Meeting, Luxembourg, January 31, 2001.
[10] Rogers T, *The II Morrow GX55 Panel-Mount GPS,* AvWeb, An Internet Avionics Review Magazine available at http://www.avweb.com/articles/gx55.html.
[11] *FAA's Plan for Transition to GPS-Based Navigation and Landing Guidance,* FAA's Office of Satellite Navigation, pp. 4.4.

II) Methods

General Approach
The basic approach used in this study was a retrospective evaluation of accidents that occurred during instrument approaches. Information from these accidents was used to estimate the safety benefits of WAAS implementation. The risks associated with precision ILS approaches, and for non-precision approaches, were calculated, normalized and compared. Factors that could be associated with increased risks such as low pilot experience or light condition were also evaluated. Once the risks of precision approaches as compared to non-precision approaches were quantified, the anticipated reduction in future accident risk (with the planned implementation of WAAS) was estimated.

Assumptions: Some basic assumptions were central to being able to evaluate the benefit of precision approach capability of WAAS. These were:

- Using precision approaches as a surrogate measure for the precision approach capability of WAAS is a valid assumption.
- The potential improvement in safety is measurable.
- Valid estimates for the terminal activity levels (primarily approach) can be made.

Data Used for Analyses
There were three types of data used for this evaluation. Data concerning accidents that occurred during instruments approaches were obtained from the National Transportation Safety Board. Information concerning airport activity and the number of instrument approaches flown were obtained from the FAA's Office of Aviation Policy and Plans (APO). These two sources of data were used for the development of accident rates. Finally, activity projections were obtained from the FAA's Office of Aviation Policy and Plans. This information was used as a frame of reference for understanding the potential reduction of future accidents with the planned implementation of WAAS. Specific steps associated with each of these data sources are described below.

NTSB Accident Records
The NTSB computerized accident database was queried to locate all accidents occurring between 1983 and 2000. The query was limited to accidents that occurred during instrument approaches in instrument meteorological conditions and which occurred between the final approach fix (FAF) and touchdown. Accidents that occurred after touchdown were not included.

The NTSB was then contacted and asked to provide the same information that was obtained through the computer query of the NTSB database. This step was done to validate and verify the accidents selected through the computer query process. The results of the two selection processes were then compared. The resulting lists were combined and used to identify the NTSB brief for each accident. The NTSB brief contains a 200 word or less summary of the accident, key information on date, location, weather, light conditions, type of aircraft, information on the pilot qualification, probable cause associated with the accident and much more.

Each of the briefs was reviewed separately by two experienced pilot analysts to validate that the accident met the study inclusion criteria mentioned above. Further, the accidents were reviewed to identify those accidents that involved mechanical failure or factors other than poor pilot procedures (such as icing). These accidents were removed since the focus this part of the study was to estimate the risk associated with flying precision verses non-precision approaches. The key assumption here was that the difference in risk, if any existed, would be associated with the actual conduct of the instrument approach, not extraneous factors such as mechanical failure or airframe icing. The results from the review by the two analysts were compared and any differences corrected by consensus opinion between the analysts. The findings from review of the NTSB briefs were used to edit the computerized NTSB instrument approach database. These data were then ported to SPSS, a statistical software program, for analysis. Data for year 2000 were dropped from the analysis when it was determined that not all accide~~nts that~~ occurred in year 2000 had yet been included in the NTSB computerized database. Information on the accidents used in this analysis can be found in Appendix 3.

Activity Data

Activity data on the number of instrument approaches flown during the study period were derived from the FAA's Office of Policy and Plans airport activity database. This data system is called the Air Traffic Activity Data System (ATADS) and is available on-line at http://www.apo.data.faa.gov/faaatadsall.HTM. These data were used to calculate instrument approach accident rates (number of accidents/divided by number of approaches flown). Conversations were held with the APO staff responsible for these data systems to ensure the data being reported was actually the information needed to calculate the accident rates

The APO data source provided the number of instrument approaches flown, by airport, for the 1994-1999. Data were not available for the previous 11 years of 1983-1993. Estimates were therefore needed of the activity for these years. Past APO activity forecasts were reviewed to determine the average rate of aviation activity increases over the 11-year time frame. A value of 2% per year was found to be fairly uniform over the time frame. Using this adjustment, the estimated number of instrument approaches for 1993 was calculated to be 98% of that for 1994 (a year in which APO reported the actual numbers). The 1992 estimated number of instrument approaches was 98% of that for 1993, and so on.[12]

While the data provided by the APO provided a count of all instrument approaches flown, it did not differentiate between precision and non-precision approaches. Determination of instrument approach activity data as either precision or non-precision at an airport was predicated on the type of runway markings at the individual airports at which instrument approaches were flown. If a runway has an precision instrument approach, it is required to have markings that identify the runway as a precision approach runway. Conversely, if a runway has a non-precision approach, it too will have runway markings that identifies that runway as having a non-precision approach.[13,14]

The FAA's Office of Airports collects data concerning the majority of airports in the United States. Data collected includes the airport location, owners, runway configurations, services available on the airport and much more including information on runway marking. These data are maintained in a database known as the 5010 database (which is named after the form used to collect the data).

For this study, the runway marking information was used to adjust the APO activity data as either precision or non-precision. If an airport only had precision approach markings on its runways, all instrument approaches to that airport reported by the FAA were considered precision instrument approaches. If the airport only had non-precision approaches marking on its runways, all instrument approaches to that airport reported by the FAA were considered non-precision instrument approaches. If an airport had a combination of precision and non-precision runway ends then a weighting factor was applied to adjust the activity data for the distribution of precision and non-precision approaches for that airport. The underlying rational is that precision approach is usually preferred (based on experience of pilots involved in this study) if available. There are times, however, when a precision approach might not be available (for example, when the winds do not favor the precision approach runway). The detailed

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[12] FAA Aviation Forecasts, 1995-2004, Office of Aviation Policy and Plans, Washington D.C.

[13] FAA Order 8260.3B, U.S. Standard for Terminal Procedures, Chapter 3.

[14] FAA Advisory Circular 150/340-1H, Standards for Airport Markings, Chapter 1.

procedures for the adjustment algorithms for those airports with both precision and non-precision approaches are provided in Appendix 1.

Historical Risk Determination

Once the historical accident data and activity data were collected, cleaned and verified the following procedures were used to determine the risks associated with both precision and non-precision approaches. The accident rate per 1,000,000 departures was calculated. This was done for both precision and non-precision approaches and was stratified by the type of operation being conducted, FAR part 121, Part 135 or Part 91. The underlying assumption is that there are significant differences in operating characteristics among these different type of operators. The results from these analyses were then used to calculate a risk ratio which is the accident rate associated with non-precision approaches divided by the accident rate associated with the precision approaches. The risk ratio provides a relative measure of the difference in risk between two different groups or populations. A risk ratio of two would indicate that one group had a risk twice that of the comparison group. A value of five would indicate an increase in risk 5-fold that of the comparison population. Risk ratios are a easy way to measure and report the differences in risk between two populations or groups.

Data Used for WAAS Benefit Projections

Once the historical accident risk had been determined, the information was used to estimate the benefits of introducing WAAS precision approaches to the National Airspace System (NAS). The projections were based on the risks associated the years of 1990-1999 rather than the risks calculated for the time period of 1983-1999. This was done since the risks associated with the 1983-1989 time period were much higher than those associated with the 1990-1999 period (although the patterns remained similar). It was decided that this was a more conservative approach since the projections would be based on more recent accident experience.

Future activity estimates of the National Airspace System (NAS) were based on forecasts provided by the FAA's Office of Aviation Policy.[15,16] These references indicate a steady growth estimate of roughly 2% for each future year. Using this information, and the information derived from the historical risk evaluation of past instrument approach accidents, the expected number of precision and non-precision accidents expected for the future were calculated. The number of fatalities expected for precision and non-precision accidents were also calculated based on the past accident experience. Once this had been achieved, the reduction of accidents and fatalities that could realistically be expected with the introduction of WAAS precision approaches was estimated. Benefits were considered to be the expected total reduction in accidents and fatalities. As described earlier, WAAS precision approach capabilities will be incremental because of the need for aircraft to be equipped with the appropriate receivers and because of the FAA's WAAS implementation schedule.

The anticipated benefits of WAAS start in 2006 with the introduction of LNAV/VNAV capability. The following benefit schedule was applied for this analysis.

- 10% of benefit in 2006
- 20% of benefit in 2007
- 30% of benefit in 2008
- 40% of benefit in 2009
- 70% of benefit in 2010

[15] FAA Long Range Aerospace Forecast, Fiscal Years 2015,2020, 2025. FAA's Office Of Aviation Policy and Plans, Document # FAA-APO-01-3, June 2001.
[16] FAA Fiscal Years Forecast 2001-2012, FAA's Office of Aviation Policy and Plans, Jan. 22, 2001

- 90% benefit in 2011
- 90% though 2020

The anticipated benefits remain constant at 90% for the balance of the projection since not all operators will incorporate the technology to use WAAS until WAAS is the only instrument approach capability available.

Limitations

The primary limitations associated with this study are the assumptions underlying the projections of the benefits. Every effort has been made to make sure the underlying assumptions are conservative and defendable (conservative in this context means that the estimate erred toward showing no benefit). If conservative assumptions are applied, and the results are still robust and significant, then it can be assumed that the benefits are probably real.

Following this conservative approach, only accidents that clearly were associated with the conduct of an instrument approach (not landing after an approach of not mechanical failure during the approach) were included. Two experienced pilot analysts made this assessment. The goal was to ensure only those accidents that involved the flying of a real instrument approach were included.

Similarly, the benefit projections were predicated on the demonstrated risks associated with accidents during the time frame of 1990-1999. As described earlier, this was due to the fact that the demonstrated risks for this time frame were lower and less variable than that for the time frame of 1983-1989. Consequently, it was decided that this was a more reliable frame of reference for future risk projections.

Finally, the methods used to estimate the past activity associated with instrument approaches, either precision or non-precision, may have introduced some systematic error. This error may have overestimated or underestimated past activity. The impact of such error, if present, is likely minimized by the fact that the error should be equal for both precision and non-precision estimates. The important metric for this evaluation is the relative difference in risk between the precision and non-precision approach. This type of error should not impact that relationship.

III) Findings

Past Accident Experience

Overall, there were 46,979 accidents included in the NTSB accident database that occurred between 1983 and 1999. Of these, 3,485 (7.4%) occurred during the approach phase of flight. For this study, a select subset of 404 approach accidents that occurred in IMC conditions were included for analysis (see description in Methods section x.x). Table 1 provides a listing of all approach accidents, and those that occurred in IMC conditions, distributed by type of operation.

Table 8: Distribution of Approach Accident by Type of Operation: 1983-1999

	All Approach Accidents	IMC Approach Accidents
FAR Part 121 Air Carrier	106	16
Far Part 135 Air Taxi	230	72
FAR Part 91 General Aviation	3149	316
Total	**3,485**	**404**

When the distribution of IMC approach accidents is evaluated by the type of approach being flown at the time of the crash (precision or non-precision), it is seen that the distribution is roughly equal. There were 203 accidents (50.2% of the total) that occurred during non-precision approaches with 201 accidents (49.8%) occurring during precision approach operations. Table 2 provides a distribution of the accidents by approach type and year for different types of operations.

Table 9 IMC Approach Accident Distribution 1983-1999

	Non-Precision Approach Accidents			Precision Approach Accidents		
Year	**121 Air Carrier**	**135 Air Taxi**	**91 General Aviation**	**121 Air Carrier**	**135 Air Taxi**	**91 General Aviation**
1983	0	3	12	0	2	12
1984	0	3	20	2	0	16
1985	0	4	21	1	4	9
1986	0	1	14	1	3	25
1987	0	4	9	1	2	7
1988	0	2	9	1	4	16
1989	1	1	5	2	4	9
1990	1	3	6	0	4	7
1991	0	2	11	1	1	8
1992	0	3	10	0	2	10
1993	0	2	9	1	3	5
1994	0	0	9	1	2	2
1995	1	2	11	0	1	8
1996	1	1	9	0	2	6
1997	0	0	3	0	2	5
1998	0	2	3	1	1	3
1999	0	0	3	0	1	2
Total	**4**	**34**	**165**	**12**	**38**	**151**
Total for all Operations	**203**			**201**		

Looking at Table 2, the great similarity of the number of accidents occurring during precision and non-precision IMC approaches might suggest that the risk of these types of approa~~ches (p~~recision and non-precision) are equal. This would be an erroneous assumption because these values have not been adjusted for the underlying activity; that is how often these types of approaches are flown. For example, during the study period of 1983 to 1999, it is estimated that there were approximately 32 million precision approaches, and 4 million non-precision approaches, flown. This represents roughly an eight fold difference. Consequently, one would expect that the accident rates (a measure of actual risk) between precision and non-precision approach accidents would differ.

Figure 1 provides a description of the accident rates for precision and non-precision approaches for the time period of 1983-1999 for all operations (121 air carrier, 135 air taxi and 91 general aviation).

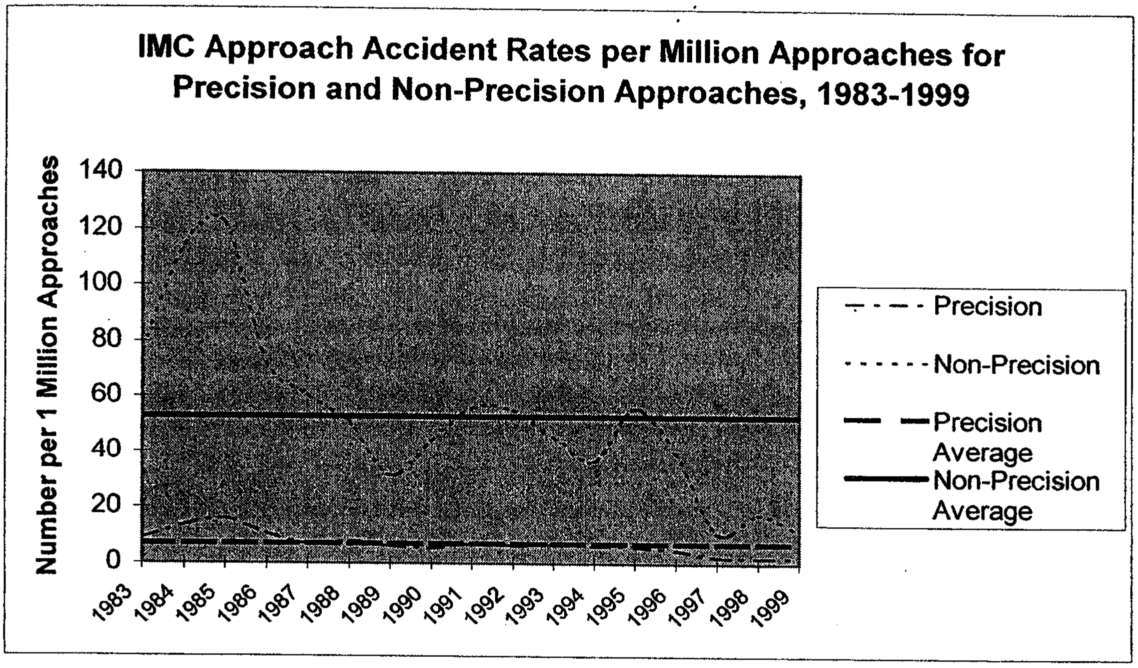

Figure 8: IMC Accident Rates for Precision and Non-Precision Approaches, 1983-1999

As can be seen, the average non-precision accident rate of 52.9 accidents per 1 million approaches is much greater than that of 6.9 for precision approaches; a 7.7 fold difference. This represents a very large difference in the risk of crashing between precision approaches and non-precision approaches.

Review of the curves contained in Figure 1 raise some important questions. For example, the differences in the accident experience among aircraft flying precision and non-precision approaches may be due to other factors such as pilot experience, type of operation, and weather conditions to name just a few. The other striking feature of the curves contained in Figure 1 is the notable reduction in the accident rate for non-precision approaches occurring after 1997 (and to a less apparent extent, for precision approaches). The following tables and figures provide some insights into these questions.

One of the first issues that should be explored is the impact of the type of operation involved in the accident. Generally speaking, FAR part 121 air carriers fly the most advanced aircraft and are crewed by two pilots, an advantage in that the two pilots split the workload. In contrast, FAR part 91 general aviation aircraft are often flown by single pilots who fly for pleasure or for transportation. It should be noted, however, that there is a significant population of professional pilots who fly under part 91. FAR part 135 pilots are usually professional pilots who fly airplanes that may be less sophisticated than those flown by the part 121 air carriers. Part 135 operations may be flown by one or ~~two pilots~~.

Table 10: IMC Approach Accident Rates Stratified by Type of Operation and Type of Approach, 1983-1999.

	Precision Approach Accident Rate per 1 Million Approaches	Non-Precision Approach Accident Rate per 1 Million Approaches	Risk Ratio
FAR Part 121 Air Carrier	0.82	7.99	9.74
FAR Part 135 Air Taxi	4.04	42.30	10.34
FAR Part 91 General Aviation	17.79	60.26	3.39

Table 3 provides insight into the risks associated with non-precision approaches among the various types of operations. What is most notable is that Part 121 operations carry the lowest overall risk followed by air taxis with general aviation having the highest risk. The other notable feature of this table is that the risk ratio (see methods section xx) is highest for air carrier and air taxi operators. Conversely, the general aviation risk ratio is relatively smaller than the other two operator populations. The smaller ratio is due to the fact that general aviation doesn't do particularly well with either precision or non-precision approaches as measured by their accident rate.

Table 11: Number of Approach Accidents Stratified by Light Condition, Approach Type, and Type of Operation 1983-1999

	Number of Precision Approach Accidents		Number of Non-Precision Approach Accidents	
	Day	**Night**	**Day**	**Night**
FAR Part 121 Air Carrier	8	4	2	2
FAR Part 135 Air Taxi	3	35	18	16
FAR Part 91 General Aviation	46	104	67	99
Total	**57**	**143**	**87**	**117**

Table 4 provides the distribution of accidents by type of operation, type of approach and the light conditions. For air carrier operations no real pattern appears although it should be noted that twice as many precision approach accidents occurred during the day (8 accidents) as occurred during the night (4 accidents). This is probably due to the fact that the majority of air carrier flights occur during the daylight hours. For air taxi operations, night accidents were far more likely for precision approaches (35 accidents) compared to day-time accidents (3 accidents). This pattern does not repeat however for non-precision approaches. For general aviation, nighttime approach accidents are more common for both precision and non-precision approaches.

Table 12: Mean Visibility Reported At Airport During IMC Instrument Approaches Where Crashes Occurred, 1983-1999

	Average Visibility During Precision Approach Accidents, SM		Average Visibility During Non-Precision Approach Accidents, SM	
	Day	**Night**	**Day**	**Night**
FAR Part 121 Air Carrier	0.6	0.5	1.0	1.7
FAR Part 135 Air Taxi	2.4	2.4	2.4	2.3
FAR Part 91 General Aviation	1.4	1.9	2.3	2.7

Table 5 provides information on the mean reported visibility as the time of the accident. The values attached with air carrier precision approaches are low as might be expected due to their operating characteristics of operating in most weather conditions. The higher values for non-precision are noted since the majority of these approaches require a visibility of at least one mile. The higher visibility associated with night non-precision approach among the general aviation population is of interest since it may provide some insight into the challenges of flying these approaches at night.

While it is not reflected in the table, the NTSB report cited fog as the restriction to visibility in 78% of all accidents. The actual visibility occurring during an approach can be very different than that reported by the weather reporting facility since fog is usually a local phenomena and not always captured by the weather observer/equipment

Table 13: Average Instrument Flight Time for Pilots Involved in IMC Approach Accidents, 1983-1999

	Average Instrument Flight Time (hours) of Pilots Involved in Precision Approach Accidents	Average Instrument Flight Time (hours) of Pilots Involved in Non-Precision Approach Accidents	Overall Average Instrument Flight Time (hours) For All Approach Accidents
FAR Part 121 Air Carrier	806	1,000	907
FAR Part 135 Air Taxi	475	604	535
FAR Part 91 General Aviation	449	394	520

Table 6 provides the average experience of the pilots involved in these accidents as measured by their reported number of hours flying on instruments. It appears that, on average, the pilots had plenty of experience.

Table 14: Accident Rate with Presence of an Operating Control Tower During Instrument Approach Accidents, 1983-1999

	Accident Rate with Operating Control Tower Present for Precision Approaches	Accident Rate with Operating Control Tower Present for Non-Precision Approaches	Risk Ratio
FAR Part 121 Air Carrier	0.75	5.99	8.0
FAR Part 135 Air Taxi	3.29	20.50	6.2
FAR Part 91 General Aviation	13.38	16.16	1.2

Table 7 provides information on the presence of an operating control tower during the instrument approach. The underlying assumption is that the presence of a control tower might be reduce the risk of the non-precision approach since the tower and the associated approach radar might be able to monitor the approach. Reviewing this table, it the presence of a control tower does not appear to have a protective effect.

Table 15: Distribution of Fatalities by Type of Operation

	Fatalities	Total Number of Occupants	Number of Accidents	Percentages of Fatalities Among Occupants
FAR Part 121 Air Carrier	151	1,178	16	13%
FAR Part 135 Air Taxi	135	247	72	55%
FAR Part 91 General Aviation	442	837	316	52%

Table 15 provides information on the risk of fatalities occurring if a accident occurs during an instrument approach. As can be seen, the approximately half the occupants in the part 135 and part 91 segments of the community are fatally injured during these types of accidents. The low number of fatalities associated with the part 121 is due to the number of events in which the aircraft was not destroyed during the accident sequence.

General Comments on Tables 3-8

It appears from the evaluation of the data contained in these tables that there are no other easily discovered factors associated with the increased risk associated with non precision approaches. This is not to say that other factors are not operating but the historical data (at this level of analysis) do not provide any indication on what they may be. It is clear that the differences in risk between approach types are real and are probably associated with the differences in how these approaches are flown.

One interesting characteristic that needs to be considered is the drop off in the accident rates for the years 1997-1999 (see Figure 1). This is a marked decrease in the rate of accidents associated with instrument approaches and appears to impact both precision and non-precision approaches. While the rates have dropped, the risk ratios patterns remain constant, 1997 is 4.7, 1998 is 8.75, 1999 is 6.0

There is no clear answer to why this has occurred. It may be due to normal variation or it may be the result of to new technology introduction or other factors? One method that can be used to explore this unexpected downturn is to compare the rates for the 1983-1989 timeframe to the ~~1990~~ 1999 timeframe.

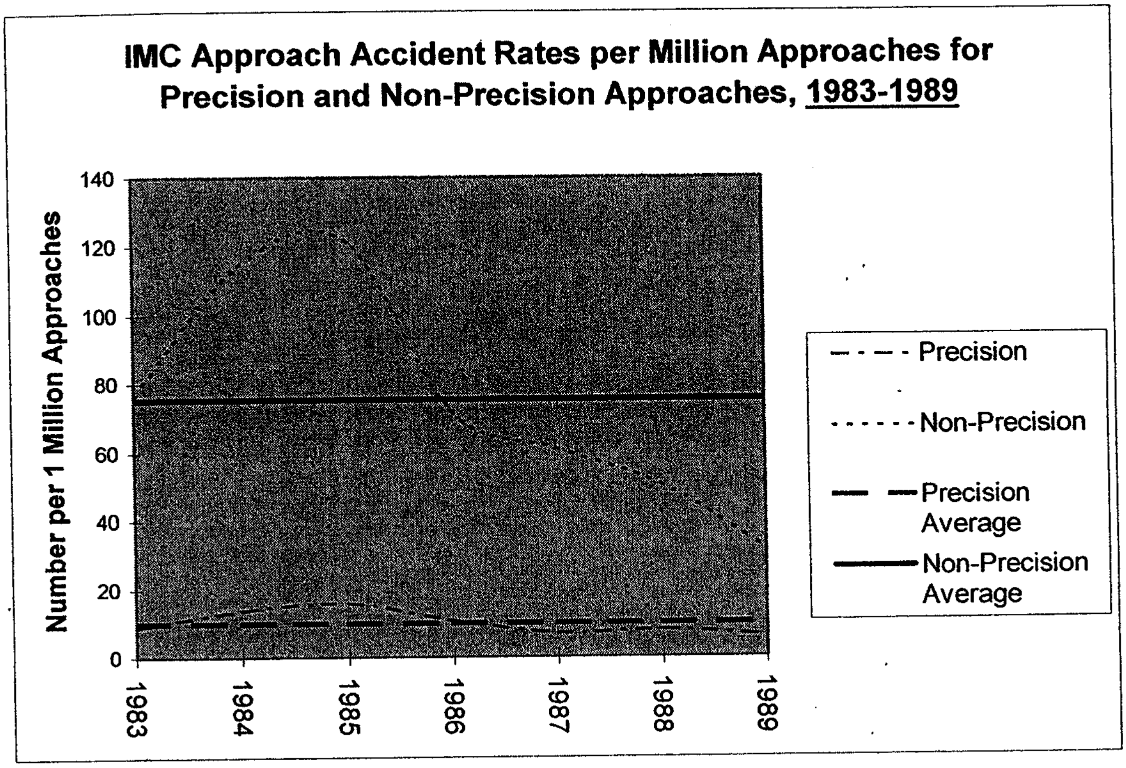

Figure 9: IMC Accident Rates for Precision and Non-Precision Approaches, 1983-1989

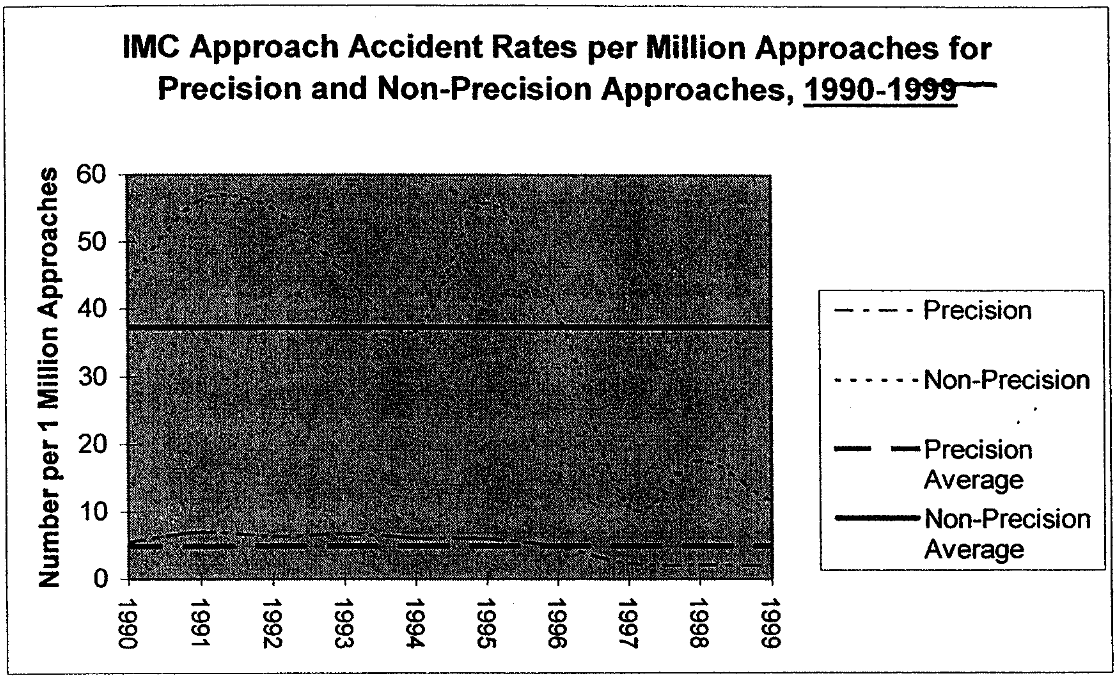

Figure 10: IMC Accident Rates for Precision and Non-Precision Approaches, 1990-1999

Review of Figures 2 and 3 demonstrate that the average rates for 83-89 were 9.97 accidents per 1 million precision approaches and 75.23 accidents per million non-precision approaches, a risk ratio of 7.5. For the time period of 90-99, the accident rate is 4.87 for precision approaches and 37.25 for non-precision approaches, a risk ratio of 7.6. While the overall accident rates have dropped for the time frame of 1990-1999, the increase in risk associated in flying non-precision approaches has remained constant.

Based on this review, accident rate values from 1990-1999 time period were used as baseline measures for the projections of WAAS benefits.

WAAS Benefit Projections

The following projections of WAAS benefits are predicated on the procedure outlined in section xx of the Methods section above. The benefits are projected for the time period of 2001-2020.

To review briefly, average accident rates for precision and non-precision accidents were determined from the analyses of past accidents from the time period of 1990-1999. These average values were used for projections of the estimates for future crashes. Activity estimates were derived from FAA Long –Range Aerospace Forecasts[17] which averaged a 2% increase in activity per year over the time period of 2001 to 2020. Finally, the implementation of WAAS capability was introduced gradually over the time period of 2006 to 2011 with full benefits being demonstrated in 2011. It should be noted that, for this evaluation, WAAS is not considered to be 100% effective in eliminating IMC non-precision approach risk since it is likely that not all operators will abandon traditional non-precision approach procedures. This is particularly true for general aviation operators.

[17] *FAA Long-Range Aerospace Forecasts Fiscal Years 2015, 2020 and 2025*, ibid

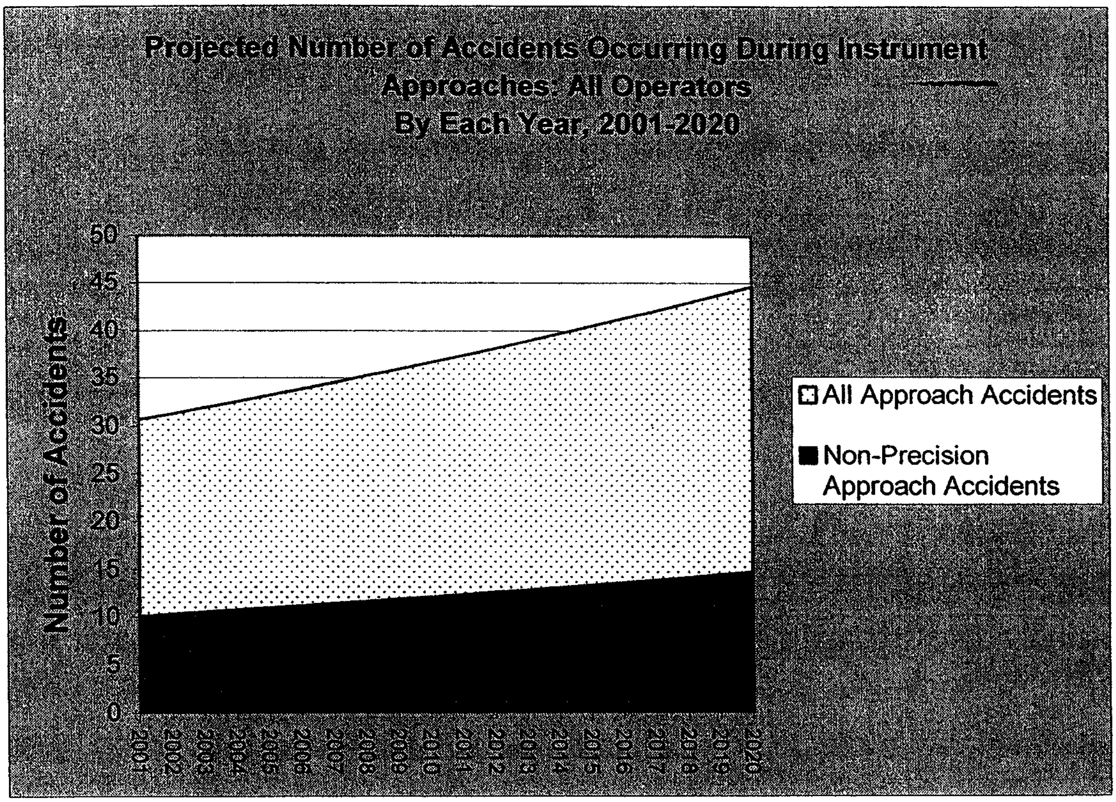

Figure 11: Projected Number of IMC Approach Accidents For Each Year, 2001-2020

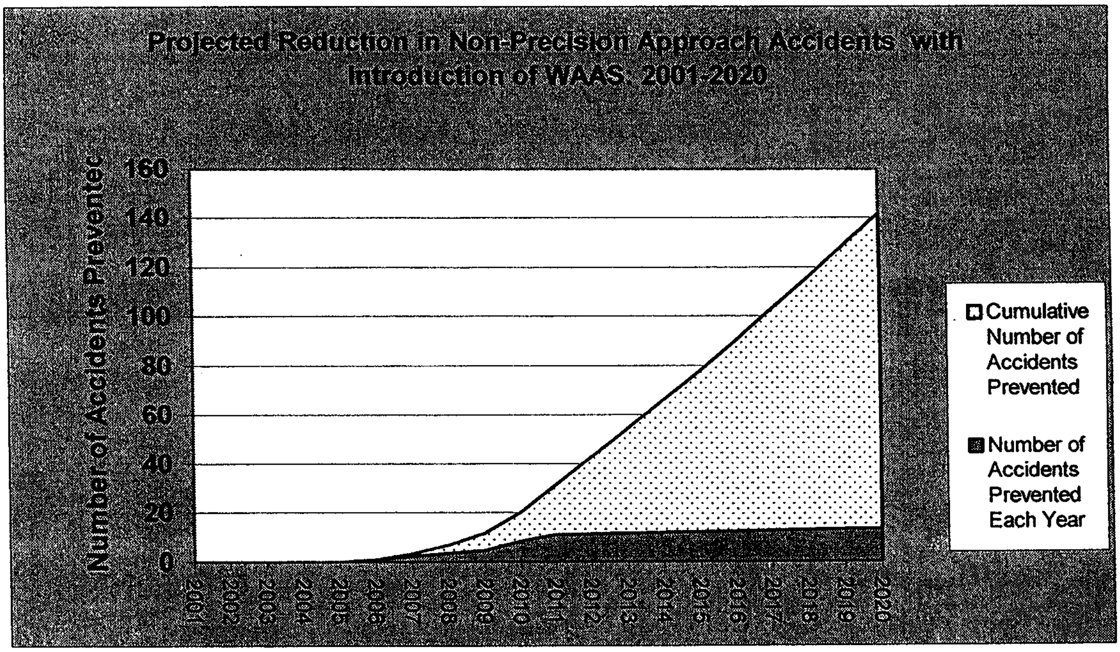

Figure 12: Cumulative Estimated Number of IMC Non-Precision Approach Accidents Prevented with the Introduction of WAAS

Review of Figure 4 shows that there is projected to be approximately 10 to 14 non-precision accidents per year over the time frame of 2001-2020. Figure 5 shows that the cumulative number of approach accidents that could be prevented through the introduction of WAAS totals 141 accidents.

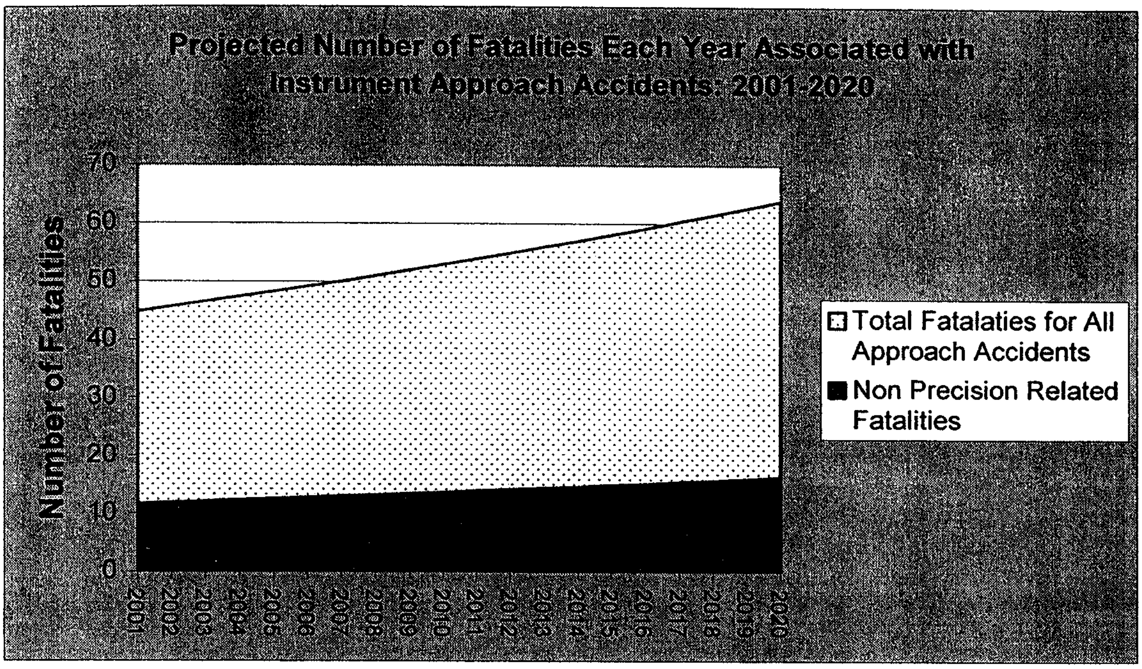

Figure 13: Projected Number of IMC Approach Related Fatalities, 2001-2020

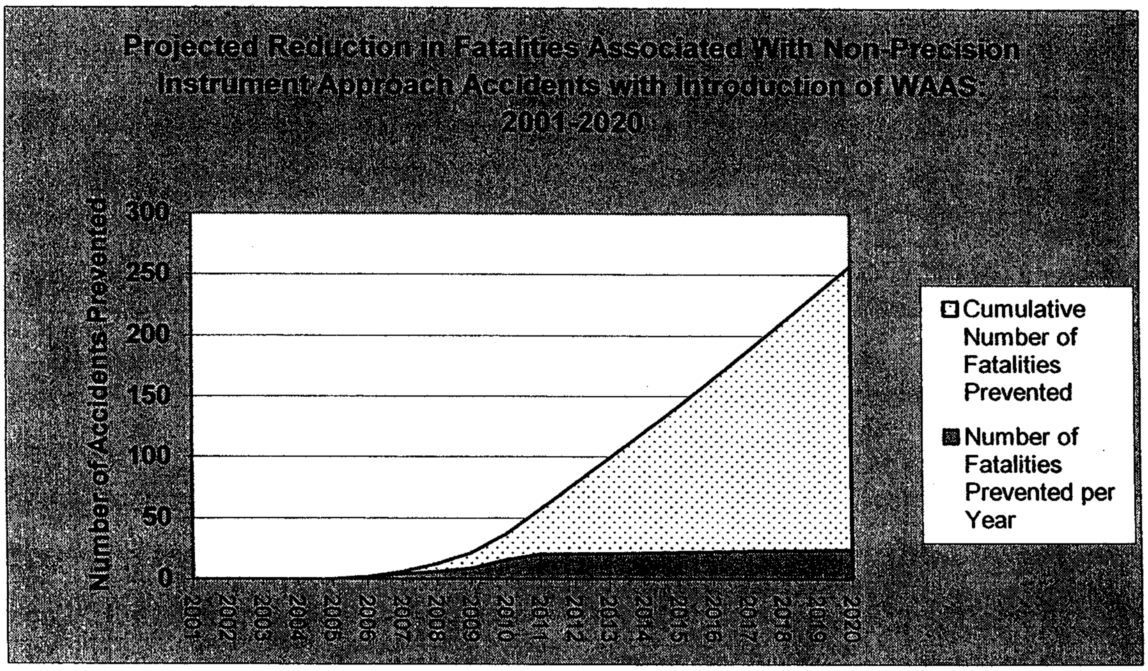

Figure 14: Cumulative Estimated Number of IMC Non-Precision Approach Related Fatalities Prevented with the Introduction of WAAS

Figure 6 shows that there are expected to be 11 to 16 fatalties per year associated with non-precision approaches for the time frame of 2001-2020. Figure 7 shows the projected reduction of fatalties for the 2001-2020 is approximately 257 people over the time frame.

IV) Discussion

It is clear that the introduction of WAAS precision approach capability will ~~introduce~~ significant safety benefits. In this analysis, evaluation of these safety benefits was limited to the reduction of accidents and deaths associated with the decrease in the reliance on non-precision approaches. This evaluation was limited to this very specific focus because it was a benefit that could be quantified and described. Based on these analyses, it was found 141 accidents could be prevented over a 20-year period and over 250 lives saved. This is a conservative estimate.

The safety improvements cited in this study may even be greater if the overall growth rate for aviation exceeds the growth rate of 2% used in this analysis. If the growth rate averages 3% per year for the period of 2001 to 2020, the total number of accidents prevented will increase to approximately 175 and the number of lives saved will increase to 315. Conversely, if the growth rate only averages 1% per year during this time period, the accidents and deaths prevented will total 114 and 206 respectively.

There are many other benefits associated with WAAS that are not as easily quantified. For example, it is reasonable to expect that pilots will use WAAS precision guidance while on approaches in non-instrument conditions. Safety benefits for this type of use include helping establish and maintain a stabilized approach, provide obstacle clearance at night when terrain features are not visible and the use during marginal visual conditions (usually considered as three to five miles visibility). These benefits would most likely be most pronounced among single-pilot flight operations.

Of course, there are safety benefits associated with the use of WAAS outside of the instrument approach scenario. As mentioned earlier, WAAS provides a three-dimensional navigation capability. Pilots will be able to accurately determine their position, altitude and ground speed. Moving map displays will help pilots maintain their situational awareness, a key component to safe flight, especially in instrument conditions. It will also encourage point-to-point navigation reducing fuel use and improving air traffic control routing flexibility. The cost of this capability, based on current GPS receiver costs, will certainly be within reach of pilots who own their own aircraft.

WAAS will ultimately eliminate the multitude of instrument approach systems throughout the county. This should significantly reduce, or eliminate, the cost of operating and maintaining these systems. Pilots will only need to learn one type of instrument approach procedure, in contrast to today's environment that requires knowledge and skill to fly a variety of precision and non-precision approaches. This will make it easier for pilots to acquire and maintain instrument approach skills.

Another benefit will be associated with those airports that currently do not have any instrument approach capability will be able to add precision approach capability assuming the airport is not surrounded by obstructions that make instrument approaches infeasible. This benefit would also be applicable to heliports at hospitals, and other location. This should improve the utility of these airports and heliports, reduce capacity demands on larger airports, and improve safety because pilots will be able to fly instrument approaches to airports or heliports that are more convenient thereby reducing the temptation fly visually to an airport not served by an instrument approach in marginal weather conditions.

The introduction of WAAS certainly is in keeping with the White House Commission on Aviation Safety (WHCAS) goal which called for an 80% reduction in fatal accidents by the year 2008.[18] The WAAS technology and improved navigation will certainly make all aviation operations easier, more efficient and

[18] White House Commission on Aviation Safety and Security: Final Report to President Clinton
Vice President Al Gore, Chairman, February 12, 1997

safer. WAAS, however, will not be able to contribute significantly to the overall reduction efforts identified by the WHCAS since their goals are targeted for completion by FY 2008. WAAS will not be fully operational until a number of years later.

V) Conclusions

- It is estimated that the introduction of WAAS into the National Air~~space~~System will prevent 141 instrument approach accidents, and 257 fatalities for the time period of 2001 to 2020. This assumes an annual growth rate in aviation traffic of 2% per year during this time period.

- If the growth rate averages 1% per year over the time period of 2001 to 2020, the reduction in instrument approach accidents and fatalities is estimated to 114 and 206 respectively.

- If the growth rate averages 1% per year over the time period of 2001 to 2020, the reduction in instrument approach accidents and fatalities is estimated to 175 and 315 respectively.

- WAAS offers a clear safety benefit in the potential to significantly reduce instrument approach accidents.

- WAAS should provide additional benefits that are not easily measured or quantified. These include:

    i. Guidance for non-instrument approaches that will help pilots fly stabilized approaches, avoid terrain during night approaches, and provide guidance in marginal visibility conditions (3 to 5 miles visibility)
    ii. Three-dimensional navigation capability that will provide accurate position information, ground speed and altitude data.
    iii. Pilots will need to learn only one type of instrument approach procedure. The multiple procedures associated with the various precision and non-precision approaches will not have to be learned. This should make it easier for pilots to maintain their instrument flying skills and reduce their risk of an accident during the instrument approach.
    iv. The integration of moving map displays during enroute and approach phases of flight, improving pilot's ability to maintain situational awareness.

- WAAS will allow the addition of precision instrument approaches at airports and heliports that currently have no instrument approach capability. This should further improve capacity and safety and improve the utility of these airports.

Appendix 1: Description of Activity Exposure Measure Determination Procedures

Activity data on the number of instrument approaches flown during the study period were derived from the FAA's Office of Policy and Plans airport activity database. This data system is called the Air Traffic Activity Data System (ATADS) and is available on-line at http://www.apo.data.faa.gov/faaatadsall.HTM. These data were used to calculate instrument approach accident rates (number of accidents/divided by number of approaches flown). Conversations were held with the APO staff responsible for these data systems to ensure the data being reported was actually the information needed to calculate the accident rates

While the data provided by the APO provided a count of all instrument approaches flown, it did not differentiate between precision and non-precision approaches. Determination of instrument approach activity data as either precision or non-precision at an airport was predicated on the type of runway markings at the individual airports at which instrument approaches were flown.

Runway marking information was used to adjust the APO activity data as either precision or non-precision. If an airport only had precision approach markings on its runways, all instrument approaches to that airport reported by the FAA were considered precision instrument approaches. If the airport only had non-precision approaches marking on its runways, all instrument approaches to that airport reported by the FAA were considered non-precision instrument approaches. If an airport had a combination of precision and non-precision runway ends then a weighting factor was applied to adjust the activity data for the distribution of precision and non-precision approaches for that airport. The weighing factors are provided below along with the underlying rational.

If an airport had both a precision and non-precision approach (a 1 to 1 ratio), the activity measure was weighted as 80% precision and 20% non-precision. The underlying rational being that an airport would install the precision approach on the runway that would be used during the majority of operations because of the operational benefits of the precision approach. The non-precision approach would be used for conditions when the ILS was not available or the winds dictated that the non-precision approach runway would be used. This general approach was used to adjust the airport instrument approach activity for all airports that had a combination of precision and non-precision approaches.

For airports that a precision to non-precision ratio of 2-1 the weighting factor applied was 90% precision, 10% non-precision.

For airports that had a precision to non-precision ratio of 3-1 the, the weighing factor applied was 95% precision and 10% non-precision.

In those circumstances where the ratios were reversed, that is, more non-precision approaches than precision approaches, similar weighting procedures were followed.

For airports that had a precision to non-precision ratio of .5-1 the, the weighing factor applied was 70% precision and 30% non-precision.

For airports that had a precision to non-precision ratio of .33-1 the, the weighing factor applied was 60% precision and 40% non-precision.

Appendix 2: Stabilized Approach Considerations

The Flight Safety Foundation identifies the following factors as central to a stabilized approach. While this guidance is provided primarily for larger turbine powered airplanes, the basic concepts and tenets described here are also applicable to smaller piston powered airplanes.[19]

Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all the following criteria are met:*

1) The aircraft is on the correct flight path;
2) Only small changes in heading/pitch are required to maintain the flight path;
3) The aircraft speed is not more than V_{ref} + 20 knots indicated airspeed and not less than V_{ref};
4) The aircraft is in the correct landing configuration;
5) Sink rate is not greater than 1,000 feet per minute; if an approach requires a sing rate greater than 1,000 feet per minute, a special briefing should be conducted;
6) Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7) All briefings and checklist have been conducted;
8) Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevations, and;
9) Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

[19] *ALAR, Approach and Landing Accident Reduction*, Flight Safety Foundation Digest, Vol. 19, No 8-11, pp 134.

Appendix 3: Listing of NTSB Accidents Used in Study

Accident Date	Airport ID	Aircraft Registration Number	NTSB ID	Airport Name	State
14-Jan-1983	GRB	N9916B	CHI83LA081	Austin Straubel	
23-Jan-1983	RFD	N61558	CHI83FA089	Rockford	IL
11-Feb-1983	3KM	N8981C	MKC83FA066	Col.James Jabara	OK
15-Feb-1983	FSD	N8478N	DEN83FTK03	Joe Foss Field	SD
23-Feb-1983	ESF	N4862G	FTW83FA126	Esler Regional	LA
24-Feb-1983	2A0	N123SM	ATL83LA120	Mark Anton	TN
16-Mar-1983	SSI	N8855V	ATL83FA176	Malcolm McKinnon	GA
27-Mar-1983	OCF	N123WK	MIA83LA105	Ocala Municipal	FL
03-Apr-1983	FRG	N8219L	NYC83FA085	Republic	NY
06-Apr-1983	IND	N3794W	CHI83FA160	Indianapolis Int'l	IN
14-Apr-1983	C29	N9215P	CHI83FA166	MOREY	WI
15-Apr-1983	BLF	N7353S	ATL83FIJ02	MERCER COUNTY	WV
12-May-1983	IXD	N725M	MKC83FA108	JOHNSON CO. INDUSTRIAL	KS
30-May-1983	FRG	N837E	NYC83FA126	REPUBLIC	NY
31-May-1983	PLB	N6207R	NYC83FA128	CLINTON COUNTY	NY
18-Sep-1983	OCH	N111QL	FTW83FA431	EAST TEXAS REGIONAL	TX
05-Oct-1983	SGF	N5191E	MKC84FA002	SPRINGFIELD REGIONAL	MO
11-Nov-1983	MYF	N911SC	LAX84FA058	MONTOGMERY FIELD	CA
27-Nov-1983	RMG	N3801N	ATL84AA053	RICHARD B. RUSSEL	GA
02-Dec-1983	GPT	N36MP	ATL84FA059	GULFPORT/BILOXI	MS
02-Dec-1983	RKR	N310JD	FTW84FA082	ROBERT S. KERR	OK
05-Dec-1983	KCK	N704M	MKC84FA033	FAIRFAX MUNI	KA
12-Dec-1983	2M2	N66MZ	ATL84MA063	LAWRENCEBURG	TN
12-Dec-1983	40N	N3298D	NYC84FA047	COATESVILLE	PA
12-Dec-1983	SWF	N6774R	NYC84FA052	STEWART	NY
14-Dec-1983	BUF	N87291	NYC84FA054	BUFFALO INT'L	NY
17-Dec-1983	LVK	N4513K	LAX84LA098	LIVERMORE	CA
21-Dec-1983	DET	N90DF	CHI84LA065	DETROIT CITY	MI
30-Dec-1983	PBI	N761HZ	MIA84FA053	PALM BEACH INT'L	FL
05-Jan-1984	PVU	N3037T	DEN84FA065	PROVO MUNI	UT
15-Jan-1984		N31844	ATL84FA083	UNK	AL
17-Jan-1984	GMU	N81717	ATL84FA084	Greenville	SC
24-Jan-1984	MEM	N46RS	ATL84FLT02	MEMPHIS INT'L	TN
24-Jan-1984	GON	N900FE	NYC84FA074	GROTON-NEW LONDON	CT
26-Jan-1984	GRE	N76AP	CHI84LA094	GREENVILLE	SC
10-Feb-1984	DRO	N6400E	DEN84FA089	DURANGO-LA PLATA	CO
17-Feb-1984	CHO	N9353Q	ATL84MA101	CHARLOTTESVILLE-ALBEMARLE	VA
19-Feb-1984	HIO	N83382	SEA84FA058	HILLSBORO	OR
25-Feb-1984	ITH	N6886D	NYC84FA092	TOMPKINS COUNTY	NY
26-Feb-1984	ELD	N33BP	MKC84FA084	GOODWIN	LA
04-Mar-1984		N60031	LAX84LA205	BRACKETT FIELD	CA
05-Mar-1984	3A1	N3291Q	ATL84MA114	FOLSOM FIELD	AL
05-Mar-1984	CBE	N6629L	NYC84MA102	CUMBERLAND	MD

14-Mar-1984	GON	N5022S	NYC84FA108	CROTON-NEW LONDON	CT
16-Mar-1984		N8482N	NYC84LA111	NORWOOD	MA
19-Mar-1984	JLN	N6665X	MKC84FA106	JOPLIN MUNI	MO
31-Mar-1984	MLS	N743W	DEN84FA121	FRANK WILEY	MT
04-Apr-1984	PTK	N3645T	CHI84FA148	PONTIAC/OAKLAND	MI
05-Apr-1984	BGM	N511SC	NYC84LA133	EDWIN A. LINK FIELD	NY
15-Apr-1984	N44	N15VP	NYC84FA138	AIR PARK AIRPORT	NJ
18-Apr-1984	BED	N4467X	NYC84FA143	HANSCOM FIELD	MA
07-May-1984		N6907L	NYC84FA163	UNKNOWN	PA
08-Jun-1984	UUK	N4206L	ANC84LA086	KUPARAK	AK
13-Jun-1984	DTW	N964VJ	DCA84AA028	DETROIT METRO	MI
30-Jun-1984	BOS	N120PB	NYC84FA227	GEN EDEWARD LAWRENCE	MA
31-Aug-1984	8A0	N55LP	ATL84FA274	ALBERTVILLE MUNI	AL
31-Aug-1984	ILM	N5071R	ATL84FA275	NEW HANOVER COMPANY	NC
21-Sep-1984	MSO	N3736Q	DEN84FA300	MISSOULA	MT
23-Oct-1984	CYS	N1569T	DEN85FA017	CHEYENNE	WY
04-Nov-1984	CEW	N9242S	MIA85FA023	BOB SIKES	FL
05-Nov-1984	GON	N62561	NYC85LA023	GROTON	CT
17-Nov-1984	IRK	N3955H	MKC85LA021	KIRKSVILLE	MO
19-Nov-1984	PPA	N54028	FTW85LA056	PERRY LEFORS	TX
30-Nov-1984	PIH	N37279	SEA85LA023	POCATELLO MUNI	ID
04-Dec-1984	LBB	N4864A	FTW85LA068	LUBBOCK INT'L	TX
06-Dec-1984	JZI	N7230R	ATL85MA049	CHARLESTON EXECUTIVE	SC
14-Dec-1984		N7329Y	DEN85FA043	UNKNOWN	NM
19-Dec-1984	GLW	N6077H	ATL85FA061	GLASGOW MUNI	KY
20-Dec-1984	ROG	N9229Y	MKC85FA037	RODGERS AIRPORT	AR
29-Dec-1984	DHN	N6527D	ATL85FA071	DOTHAN	AL
01-Jan-1985	LEB	N47364	NYC85FNC02	LEBANON	NH
04-Jan-1985	W97	N275MA	BFO85FA011	WEST POINT AIRPORT	VA
19-Jan-1985	ABI	N735QN	FTW85LA098	ABILINE	TX
04-Feb-1985	SXQ	N50NP	DCA85AA012	SOLDOTNA	AK
13-Feb-1985	8G5	N2019U	NYC85FA064	ST. MARYS	PA
20-Feb-1985	HUT	N617CA	MKC85FCQ01	HUTCHINSON MUNI	KS
22-Feb-1985	UIZ	N100RN	CHI85FA120	BERZ-MACOMB	MI
06-Apr-1985	ACK	N68DD	NYC85FA099	NANTUCKET	MA
20-Apr-1985	ACY	N4972S	NYC85FA110	ATLANTIC CITY	NJ
17-May-1985	LBE	N66892	NYC85FA125	WESTMORLAND COUNTY	PA
21-May-1985	CRW	N8460M	ATL85FA171	CHARLESTON WEST VIRGINIA	WV
21-May-1985	HRO	N10GE	MKC85FA110	BOONE COUNTY	AR
18-Jul-1985	ACK	N8247A	NYC85LA184	NANTUCKET	MA
02-Aug-1985	DFW	N726DA	DCA85AA031	DFW AIRPORT	TX
25-Aug-1985		N300WP	DCA85AA035	AUBURN-LEWISTON	ME
16-Sep-1985		N8139P	CHI85FA379	CLOQUET	MN
25-Sep-1985	HTS	N25Q	ATL85FA283	TRISTATE WALKER LONG FIEL	WV
04-Oct-1985	GAI	N2106X	BFO86FA002	MONTGOMERY COUNTY	MD
22-Oct-1985	JNU	N456JA	SEA86MA018	JUNEAU INT'L	AK
30-Oct-1985	FZG	N8401E	ATL86FA014	FITZGERALD MUNI	GA

01-Nov-1985	ENW	N92302	CHI86LA022	KENOSHA MUNI	WI
03-Nov-1985	GSP	N733KU	ATL86LA018	GREER	SC
09-Nov-1985	APA	N1909T	DEN86FA020	CENTENNIAL	CO
11-Nov-1985	LBE	N59MD	CHI86MA025	WESTMORLAND COUNTY	PA
12-Nov-1985	DTW	N6788Y	CHI86FA026	WAYNE COUNTY	MI
12-Nov-1985	PPA	N6843Q	FTW86FA024	PERRY LEFORES FIELD	TX
12-Nov-1985	3KM	N3864P	MKC86FA026	JABARA AIRPORT	KS
13-Nov-1985	ELZ	N1400H	NYC86FA034	WELLSVILLE	NY
14-Nov-1985	EDE	N735SS	ATL86FA025	EDENYON MUNI	NC
16-Nov-1985	IDA	N124RS	SEA86LA024	IDAHO FALLS	ID
24-Nov-1985		N86JB	MKC86FA030	FAYETTEVILLE	AR
25-Nov-1985	DSM	N81589	MKC86MA031	DES MOINES	IA
27-Nov-1985		N220F	ATL86FA032	T.F. GREEN	RI
01-Dec-1985	17A	N9289J	ATL86FA034	GWINNETT COUNTY	GA
01-Dec-1985	MIV	N26FM	BFO86FA008	MILLIVILLE MUNI	NJ
07-Dec-1985	IDA	N5635D	SEA86LA029	IDAHO FALLS	ID
11-Dec-1985	ELM	N7770Y	ATL86FA039	ELMIRA	NY
23-Dec-1985	CRR	N1494G	LAX86MA074	BUCHANAN FIELD	CA
29-Dec-1985	SLC	N2082S	DEN86FA056	SALT LAKE CITY INT'L	UT
03-Jan-1986	HFD	N3349R	NYC86FA057	HARTFORD-BRAINARD	CT
04-Jan-1986	MSY	N9253Y	FTW86FA031	MOISNAT	LA
09-Jan-1986	JAX	N700CM	MIA86MA057	JACKSONVILLE INT'L	FL
10-Jan-1986	SLC	N757ZE	DEN86FA060	SALT LAKE CITY INT'L	UT
19-Jan-1986		N34069	NYC86LA064	REPUBLIC AIRPORT	NY
07-Feb-1986	LYH	N9477C	BFO86FA015	LYNCHBURG MUNI	VA
08-Feb-1986	HRL	N871AA	DCA86IA017	RIO GRAND VALLEY	TX
17-Feb-1986	CRQ	N9253H	LAX86FA120	MCCLELLAN-PALOMAR	CA
18-Feb-1986	RST	N3940C	CHI86LA090	ROCHESTER MUNI	MN
20-Feb-1986	3WE	N111MM	MKC86LA062	WEISS/WILMINGTON	DE
26-Feb-1986	SNA	N58SB	LAX86FA127	JOHN WAYNE	CA
13-Mar-1986	TOL	N3124P	ATL86FA092	TOLEDO	OH
13-Mar-1986	APN	N1356P	DCA86AA021	PHELPS-COLLINS	MI
23-Mar-1986	BFA	N43769	CHI86FA108	BOYNE MOUNTAIN	MI
15-Apr-1986	FOK	N4559X	NYC86LA105	SUFFOLK COUNTY	NY
02-May-1986	IAH	N69668	FTW86MA074	HOUSTON INTERCONTINENTAL	TX
07-May-1986	BIL	N577KA	DEN86FA128	LOGAN	MT
07-Jun-1986	ENW	N1268Z	CHI86FA151	KENOSHA MUNI	WI
23-Jun-1986	BFD	N4445D	NYC86FA158	BRADFORD	PA
01-Jul-1986	LYH	N133P	BFO86FA038	LYNCHBURG MUNI	VA
16-Jul-1986	MKG	N6857E	CHI86FA172	MUSKEGAN COUNTY	MI
23-Jul-1986	MOB	N2952D	ATL86LA207	BATES FIELD	AL
28-Jul-1986	CKB	N96701	ATL86FA212	BENEBUM AIRPORT	WV
17-Aug-1986	MTN	N31AB	BFO86FA042	GLENN L MARTIN STATE	MD
17-Sep-1986	UIN	N71650	CHI86LA224	QUINCY	IL
19-Sep-1986	ISW	N4909F	CHI86FEP09	ALEXANDER FIELD	WI
28-Sep-1986	W09	N6443Q	BFO86FA050	LEESBURG MUNI	VA
20-Oct-1986	BNA	N5260F	ATL87FA007	NASHVILLE	TN

26-Oct-1986	FDK	N4347X	BFO87FA004	FREDERICK	MD
05-Nov-1986	MYF	N399WM	LAX87LA033	MONTGOMERY	CA
06-Nov-1986	CYS	N8216V	DEN87FA017	CHEYENNE	WY
17-Nov-1986	ALN	N1631E	CHI87LA019	ALTON ST LOUIS REGIONAL	IL
26-Nov-1986	INT	N9592Y	ATL87FA029	SMITH REYNOLDS	NC
26-Nov-1986	IPT	N8130A	NYC87FA038	WILLIAMSPORT	PA
02-Dec-1986	PIA	N9210M	CHI87FA040	GREATER PEORIA AIRPORT	IL
06-Dec-1986	TWF	N37561	SEA87LA020	JOSLIN FIELD	ID
10-Dec-1986	PSF	N65TD	ATL87MA041	PITTSFIELD	MA
15-Dec-1986	SLC	N164SW	SEA87FA036	SALT LAKE CITY INT'L	UT
17-Dec-1986	BMG	N9603B	CHI87LA051	MONROE COUNTY	IN
22-Dec-1986	DPA	N1253R	CHI87FA054	DUPAGE	IL
23-Dec-1986	SAV	N4137Q	ATL87FA047	SAVANNAH INT'L	GA
24-Dec-1986		N414LL	MKC87FA035	OLATHA	KS
27-Dec-1986	TRI	N210M	ATL87FA051	TRI-CITY REGIONAL	TN
27-Dec-1986	FLL	N84136	MIA87FA062	FT LAUDERDALE INT'L	FL
07-Jan-1987	MLS	N57133	DEN87FA042	WILEY	MT
28-Jan-1987	ANC	N7393U	ANC87FA028	ST MARY'S MUNI	AK
18-Feb-1987	BNA	N31590	ATL87LA073	NASHVILLE METROPOLITAN	TN
08-Mar-1987	AVL	N621M	ATL87FA082	ASHVILLE REGIONAL	NC
20-Mar-1987	LWM	N200FD	NYC87LA113	LAWRENCE	MA
28-Mar-1987	GED	N2221E	ATL87FA100	GEORGETOWN, SUSSEX COUNTY	DE
13-Apr-1987	MCI	N144SP	DCA87MA026	KANSAS CITY INT'L	MO
17-Apr-1987	THV	N7987W	NYC87FA127	YORK-THOMASVILLE	PA
28-Apr-1987		N13808	NYC87LA135	PORTLAND	ME
20-May-1987	COD	N2336X	DEN87FA130	E.E. FAUST REGIONAL	WY
21-Jun-1987	MKE	N2678R	CHI87FA153	GEN MITCHELL FIELD	WI
26-Jun-1987	BOS	N33670	NYC87FA187	LOGAN INT'L	MA
24-Jul-1987	MRY	N82793	LAX87FA281	MONTERRY	CA
22-Aug-1987	ACK	N83232	NYC87FAMS2	NANTUCKET	MA
10-Sep-1987	S47	N9484R	SEA87FA185	TILAMOOK	OR
11-Sep-1987	6B6	N25223	NYC87FA251	MINUTE MAN	MA
19-Sep-1987	FIT	N99151	NYC87LA261	FITCHBURG MUNI	MA
30-Sep-1987	MMTJ	XAKOA	LAX87FA350	GEN RODRIGUEZ INT'L	ME
25-Oct-1987	MHE	N1257E	DEN88FA016	MITCHELL MUNI	SD
03-Nov-1987	MCO	N888DJ	MIA88LA026	ORLANDO INT'L	FL
28-Nov-1987	ASG	N201CQ	MKC88LA022	SPRINGDALE	AR
14-Dec-1987	JLN	N331PX	MKC88FA027	JOPLIN MUNI	MO
18-Dec-1987	4R2	N33007	FTW88FA038	HORSESHOE BAY	TX
07-Jan-1988	APC	N2938X	LAX88FA082	NAPA COUNTY	CA
18-Jan-1988	MDH	N40265	CHI88FA046	SOUTHERN ILLINOIS	IL
18-Jan-1988	HOU	XAKUT	FTW88MA048	HOUSTON HOBBY	TX
18-Jan-1988	STL	N200RS	MKC88FA041	LAMBERT=ST. LOUIS	MO
19-Jan-1988	CLT	N996SA	ATL88LA083	CHARLOTTE-DOUGLAS	NC
19-Jan-1988	DRO	N68TC	DCA88MA017	DURANGO	CO
31-Jan-1988	PUB	N9393H	DEN88LA073	PUEBLO	CO
01-Feb-1988	KTN	N3689D	SEA88LA043	KETCHIKAN	AK

03-Feb-1988	HLN	N517S	DEN88FA063	HELENA REGIONAL	MT
18-Feb-1988	LCH	N5701K	FTW88FA063	LAKE CHARLES MUNI	LA
19-Feb-1988	ACY	N27400	NYC88FA087	ATLANTIC ~~CITY~~	NJ
19-Feb-1988	BDR	N2469M	NYC88FA093	IGOR SIKORSKY MEMORIAL	CT
20-Feb-1988	MMU	N5782E	NYC88LA088	MORRISTOWN	NJ
24-Mar-1988	AMN	N54848	CHI88FA082	ALMA	MI
01-Apr-1988		N32076	CHI88FA090	QUINCY MUNI-BALDWIN FIELD	IL
01-Apr-1988	MKC	N989B	MKC88FA072	KANSAS CITY DOWNTOWN	MO
08-Apr-1988	HLN	N8008M	DEN88FA093	HELENA REGIONAL	MT
31-Aug-1988	CRW	N15948	BFO88LA080	CHARLESTON-YEAGER	WV
23-Sep-1988	EUG	N234K	SEA88LA184	MAHLON SWEET	OR
12-Oct-1988	SMX	N6198H	LAX89FA013	SANTA MARIA	CA
19-Oct-1988		N739YS	LAX89FA021	PASO ROBLES	CA
21-Oct-1988	FDK	N8291Z	BFO89FA003	FREDERICK	MD
26-Oct-1988	L12	N79HW	LAX89FA025	REDLANDS MUNI	CA
02-Nov-1988	IAH	N60819	FTW89FA012	HOUSTON INTERCONTINENTAL	TX
18-Nov-1988	BVX	N308PS	MKC89FA027	BATESVILLE REGIONAL	AR
20-Nov-1988	OXC	N468CM	NYC89LA034	OXFORD WATERBURY	CT
30-Nov-1988	MOD	N5852V	LAX89LA041	MODESTO CITY	CA
02-Dec-1988	S88	N2706F	SEA89FA021	ARLINGTON MUNI	WA
09-Dec-1988	TYS	N120G	ATL89FA054	MCGHEE TYSON	TN
22-Dec-1988	CWA	N427MQ	CHI89IA034	CENTRAL WISCONSIN	WI
24-Dec-1988		N5121J	CHI89FA035	MADISON INDIANA	IN
24-Dec-1988	BDR	N262C	NYC89FA059	SIKORSKY MEMORIAL	CT
01-Jan-1989		N2305U	CHI89FA038	SPRINGFIELD	IL
02-Jan-1989	MFD	N500V	ATL89FA065	MANSFIELD MUNI	OH
09-Jan-1989	OAK	N1672T	LAX89FA081	OAKLAND INT'L	CA
11-Jan-1989	NC14	N9330B	ATL89FA071	ROCKINGHAM COUNTY-SHILOH	NC
22-Jan-1989	SLC	N712PC	DEN89IA067	SALT LAKE CITY INT'L	UT
17-Mar-1989	GLS	N5280R	FTW89LA068	SCHOLES FIELD	LA
22-Mar-1989	JAX	N77BR	MIA89FA113	JACKSONVILLE INT'L	FL
26-Apr-1989	DEC	N9637F	CHI89FA078	DECATUR	IL
14-Aug-1989	LDJ	N759MN	NYC89FA190	LINDEN	NJ
08-Sep-1989	MCI	N283AU	DCA89IA071	KANSAS CITY INT'L	MO
01-Oct-1989	TDF	N53CC	FTW90FA002	PERSON COUNTY	FL
01-Nov-1989	RSW	N50TR	MIA90FA022	SOUTHWEST FLORIDA REGONAL	FL
12-Nov-1989	CMA	N2723R	LAX90FA031	CAMARILLO	CA
15-Nov-1989	HPX	N55399	NYC90FA030	WEST CHESTER COUNTY	NY
22-Nov-1989	JST	N1028Q	NYC90LA032	JOHNSTOWN CAMBRIA COUNTY	PA
22-Nov-1989	PWT	N8918A	SEA90FA021	BREMERTON	WA
27-Nov-1989	DMS	N919S	DEN90FA027	DES MOINES INT'L	IA
02-Dec-1989	SRR	N9PU	DEN90FA030	SIERRA BIANCA REGIONAL	CA
08-Dec-1989	TLH	N404EA	MIA90IA038	TALLAHASSE	FL
10-Dec-1989	57A	N5417C	ATL90FA038	RUTHERFORD COUNTY	NC
16-Dec-1989	APA	N477T	DEN90FA033	CENTENNIAL	CO
26-Dec-1989	PSC	N410UE	DCA90MA011	TRI-CITIES	WA
15-Jan-1990	EKO	N2721M	DEN90FA042	ELKO MUNI	NV

16-Jan-1990	ATW	N87163	CHI90FA065	OUTGAMIE COUNTY	WI
16-Jan-1990	CWA	N4532Q	CHI90FA066	CENTRAL WISCONSIN	WI
16-Jan-1990	BTV	N5115J	NYC90FA054	BURLINGTON	VT
19-Jan-1990	LIT	N46TE	MKC90MA049	ADAMS FIELD	AR
19-Feb-1990	TLH	N7574Y	MIA90IA072	TALLAHASSE	FL
27-Feb-1990	DEN	N820FE	DEN90FA068	STAPLETON INTL	CO
19-Mar-1990	FUL	N2985E	LAX90FA123	FULLERTON MUNI	CA
27-Mar-1990	UVA	N696JB	FTW90LA087	GARNER FIELD	TX
04-May-1990	ILM	N418NE	ATL90FA108	NEW HANOVER	NC
15-May-1990	DBQ	N111AY	MKC90LA108	DUBUQUE	IA
20-May-1990	CGF	N4859W	CHI90FA131	CUYAHOGA COUNTY	OH
02-Jun-1990	UNK	N670MA	DCA90MA030	UNALAKLEET	AK
24-Aug-1990	B05	N85HB	NYC90FA199	BOSTON/LOGAN	MA
19-Sep-1990	CBE	N8249J	BFO90FA076	CUMBERLAND MUNI	WV
24-Sep-1990	SBP	N79DD	LAX90FA332	SAN LUIS OBISPO	CA
28-Sep-1990	ACK	N5289N	NYC90FA231	NANTUCKET MEMORIAL	MA
20-Nov-1990	CVN	N22054	DEN91FA020	CLOVIS MUNICIPAL	
23-Nov-1990	ACY	N2693F	NYC91FA035	ATLANTIC CITY INTL	NJ
25-Nov-1990	3KM	N6026G	CHI91FA033	COL JAMES JABARA	KS
01-Dec-1990		N437OZ	SEA91LA032	PORTLAND	OR
06-Jan-1991	RBL	N66SL	LAX91LA067	RED BLUFF	OR
19-Jan-1991	114	N4827W	ATL91FA040	STARKVILLE	MS
30-Jan-1991	JST	N30SE	NYC91LA068	JOHNSTONW-CAMBRIA COUNTY	
06-Feb-1991	CGI	N3966X	CHI91FA091	CAPE GIRANRDEAU MUNI	MO
13-Feb-1991	ASE	N535PC	DEN91FA043	SARDY FIELD	
12-Mar-1991	OGA	N6687U	CHI91LA106	LINCOLN	NE
14-Mar-1991		N3529Y	BFO91FA031	BLUEFIELD, VA	VA
17-Mar-1991	TVF	N8290Y	CHI91FA108	THIEF RIVER REGIONAL	
29-Mar-1991	CEZ	N3851C	DEN91FA056	CORTEZ-MONTEZUMA COUNTY	
09-Apr-1991	EAU	N8012T	CHI91FA126	EAU CLAIR	
15-May-1991	BNA	N882AA	ATL91IA094	NASHVILLE INTERNATIONAL	TN
07-Jul-1991	5BD	N43ER	NYC91FA174	WINDHAM	CT
10-Jul-1991	BHM	N7217L	DCA91MA042	BIRMINGHAM	AL
06-Aug-1991	OTM	N61568	CHI91FA254	OTTUMJWA	IA
27-Oct-1991	GON	N14256	NYC92LA020	GROTON-NEW LONDON	CT
11-Nov-1991	CCY	N9161P	CHI92LA026	CHARLES CITY	
14-Nov-1991	ICT	N412GK	CHI92FA028	WICHITA	KS
16-Nov-1991	81J	N951FE	ATL92FA024	DESTIN FT WALTON	FL
22-Nov-1991		N24169	CHI92FA032	COLUMBUS	OH
02-Dec-1991	MNZ	N6890T	FTW92LA032	HAMILTON	
08-Dec-1991		N8411A	CHI92LA043	SPRINGFILED	MO
20-Dec-1991	FLG	N766BA	LAX92FA065	FLAGSTAFF	AZ
26-Dec-1991	MSO	N6408P	SEA92LA031	MISSOULA	MT
03-Jan-1992	SLK	N55000	DCA92MA016	ADIRONDACK	NY
11-Feb-1992	LAL	N66LM	MIA92FA085	LAKELAND REGIONAL	FL
13-Feb-1992	MCN	N89071	ATL92LA044	LEWIS B WILSON	GA
18-Feb-1992	RDU	N33464	ATL92FA047	RALEIGH-DURHAM	NC

24-Feb-1992	UNV	N6928L	NYC92FA067	UNIVERSITY PARK	PA
06-Mar-1992	FDK	N8104G	BFO92FA031	FREDERICK MUNICIPLE	MD
07-Mar-1992	EKM	N105A	CHI92LA106	ELKHART	IN
19-Mar-1992		N65737	BFO92FA044	WASHINGTON dc	MD
04-Apr-1992	OTZ	N3555C	ANC92LA058	KOTZEBUE	AK
09-Apr-1992		N105FL	MIA92GA107	TALLAHASSEE	FL
08-Jun-1992	ANB	N118GP	ATL92MA118	ANNISTON METRO	AL
24-Aug-1992	MQT	N738HM	CHI92FA254	MARQUETTE COUNTY	MI
05-Sep-1992	GED	N3647T	BFO92FA125	COLUMBUS	OH
18-Sep-1992	MVY	N102SR	BFO92FA151	MARTHAS VINYARD	MA
18-Oct-1992	FUL	N9SQ	LAX93FA014	FULLERTON MUNI	CA
19-Oct-1992	ORH	N1ZB	NYC93FA026	WORCESTER MUNI	MA
30-Oct-1992	UCY	N101KH	ATL93LA019	EVERETT-STEWART	TN
09-Nov-1992	BOI	N7381U	SEA93FA020	BOISE	ID
30-Nov-1992	C18	N244JH	CHI93LA047	FRANKFORT	IL
11-Dec-1992	TWF	N856M	SEA93LA036	HAILEY	ID
13-Dec-1992	CID	N17CH	CHI93LA052	CEDAR RAPIDS	IA
13-Dec-1992		N7285R	SEA93FA039	OCEAN SHORES	WA
21-Dec-1992		N9319C	ATL93FA039	COLUMBUS	GA
26-Dec-1992	X41	N5343T	MIA93FA036	TAMPA BAY EXECUTIVE	FL
28-Dec-1992	TUL	N3809Q	FTW93FA061	TULSA	OK
07-Jan-1993	MYZ	N8016M	CHI93LA066	MARYSVILLE	MO
22-Jan-1993	CGF	N2890A	NYC93LA054	CUYAHOGA COUNTY	OH
29-Jan-1993	MRF	N363N	FTW93LA077	MARFA MUNICIPAL	TX
27-Feb-1993	ERW	N88KH	FTW93FA092	KERRVILLE	TX
15-Mar-1993		N4341P	FTW93LA106	TULLAHOMA	TN
06-Apr-1993	CPR	N96JP	SEA93FA088	NATRONA COUNTY INTNL	WY
04-May-1993	LNR	N80CB	CHI93FA158	TRI-COUNTY INTERNATIONAL	WI
07-Aug-1993	AGS	N90BP	ATL93FA143	BUSH FIELD	GA
18-Aug-1993	MGW	N3552R	NYC93LA161	MORGANTOWN MUNI	WV
08-Oct-1993	BVY	N6AP	NYC94FA007	BEVERLY MUNI	MA
12-Oct-1993		N6198A	FTW94LA016	ALICE	TX
31-Oct-1993	I77	N252G	NYC94FA025	CINCINNATI-BLUE ASH	OH
28-Nov-1993	BTP	N707JS	BFO94FA021	BUTLER COUNTY	PA
01-Dec-1993	HIB	N334PX	DCA94MA022	CHISHOLM-HIBBING	MN
02-Dec-1993	1M8	N39595	NYC94LA030	HOPKINSVILLE-CHRISTIAN	KY
04-Dec-1993	HVN	N1488X	NYC94FA033	TWEED-NEW HAVEN	CT
05-Dec-1993	DBQ	N9684X	CHI94LA045	DUBQUE MUNICIPAL	IA
08-Dec-1993	DFW	N166AW	FTW94IA046	DFW INTERNATIONAL	TX
09-Dec-1993	AIG	N550BC	CHI94FA048	LANGLADE COUNTY	WI
14-Dec-1993	GEG	N999VP	SEA94FA040	SPOKANE INTERNATIONAL	WA
01-Jan-1994	81J	N243KW	MIA94FA044	DESTIN-FT WALTON BEACH	FL
07-Jan-1994	CMH	N304UE	DCA94MA027	PORT COLUMBUS INTL	OH
20-Feb-1994	3GV	N58325	CHI94FA089	EAST KANSAS CITY	MO
03-Mar-1994	FOK	N512SK	NYC94FA052	SUFFOLK COUNTY	NY
11-Apr-1994	SUS	N9187M	CHI94LA130	SPIRIT OF ST LOUSI	MO
13-May-1994	H21	N4226B	CHI94FA157	CAMDENTON MEMORIAL	MO

18-Jun-1994	JYO	N6679U	BFO94LA106	LEESBURG MUNICIPLE	VA
18-Jun-1994	IAD	XABBA	DCA94MA061	WASHINGTON DULLES INTL	VA
20-Oct-1994	JVY	N40509	CHI95FA018	JEFFERSNVILLE CLARK CO	IN
18-Nov-1994	HYA	N402BK	NYC95FA030	BARNSTABLE MUNICIPLE	MA
18-Nov-1994	6B6	N14315	NYC95LA029	MINUTE MAN AIRFIELD	MA
21-Nov-1994	N88	N2949Q	NYC95FA033	DOYLESTOWN	PA
27-Nov-1994	GSP	N6556M	ATL95LA020	GREENVILLE SPARTANBURG	SC
08-Dec-1994	MCI	N5647D	CHI95LA053	KANSAS CITY INTERNATIONAL	MO
18-Jan-1995	JAC	N5603S	SEA95FA038	JACKSON HOLE	WY
21-Jan-1995	LGD	N36PB	SEA95LA039	LA GRANDE	OR
02-Mar-1995		N9448B	FTW95FA129	TULSA	OK
03-Mar-1995	GVL	N227DM	ATL95FA057	LEE GILMER MEMORIAL	GA
22-Mar-1995	RNO	N9417B	LAX95FA141	RENO CANNON INTERNATIONAL	NV
09-May-1995	OLY	N81TS	NYC95FA105	OLNEY NOBLE	IL
02-Jun-1995	VPZ	N8447T	CHI95LA166	PORTER COUNTER MUNICIPAL	IN
05-Jul-1995	RDU	N15743	ATL95FA128	RALEIGHT DURHAM INTL	NC
18-Sep-1995	CNO	N693PG	LAX95FA338	CHINO	CA
27-Sep-1995	CAE	N2160E	ATL95FA174	COLUMBAI METROPOLITAN	SC
04-Oct-1995	ELM	N9461E	NYC96FA002	ELMIRA CORNING	NY
27-Oct-1995	LGB	N2167F	LAX96LA024	DAUGHERTY FIELD	CA
10-Nov-1995	RPB	N9894R	CHI96LA031	BELLEVILLE	KS
12-Nov-1995	BDL	N566AA	DCA96MA008	BRADLEY INTERNATIONAL	CT
20-Nov-1995	FUL	N888JK	LAX96FA050	FULLERTON MUNI	CA
25-Nov-1995	BZN	N3729T	SEA96FA024	GALLATIN FIELD	MT
03-Dec-1995	2G9	N8775W	CHI96FA045	SOMERSET COUNTY	PA
19-Dec-1995	EQY	N4219T	ATL96LA024	MONROE AIRPORT	NC
19-Dec-1995		N83492	MIA96FA048	WICHITA FALLS	TX
22-Dec-1995	FCM	N222RB	CHI96LA057	FLYING CLOULD	MN
30-Dec-1995	EGV	N991PC	CHI96FA067	EAGLE RIVER UNION	WI
30-Dec-1995	DLO	N7337R	LAX96FA086	DELANO MUNICIPLE	CA
31-Dec-1995	MKY	N91MJ	MIA96FA051	MARCO ISLAND	FL
08-Jan-1996	GEG	N117AC	SEA96FA040	SPOKANE INTERNATIONAL	WA
16-Jan-1996	FFC	N9210F	ATL96FA036	FALCON FIELD	GA
22-Feb-1996	PLD	N5024J	CHI96FA095	PORTLAND	IN
01-Mar-1996		N2456U	MIA96FA089	GAINSVILLE	FL
18-Mar-1996		N54839	IAD96FA050	WISE	VA
08-May-1996	UGN	N225BA	CHI96FA152	WAUKEGAN REGIONAL	IL
09-May-1996	OLE	N65792	NYC96LA102	CATTARAUGUS COUNTY-OLEAN	NY
07-Jun-1996	SBA	N4303X	LAX96FA226	SANTA BARBARA MUNI	CA
03-Jul-1996	ISO	N23806	MIA96LA174	KINSTON REGIONAL JETPORT	NC
02-Oct-1996	W32	N2881W	IAD97FA001	HYDE FIELD	MD
08-Oct-1996	PAE	N761TQ	SEA97FA005	SNOHOMISH CO./PAYNE FIELD	WA
19-Oct-1996	LGA	N914DL	NYC97MA005	LAGUARDIA	NY
22-Oct-1996	UCA	N4564K	IAD97FA011	ONEIDA COUNTY	NY
12-Nov-1996	PVW	N5443	FTW97LA040	HALE COUNTY	TX
15-Nov-1996	SGF	N5083C	CHI97FA027	SPRINGFIELD REGIONAL	IL
30-Nov-1996	MFD	N9129N	IAD97FA025	MANSFIELD MUNI	OH

11-Dec-1996	ELZ	N3424N	IAD97LA031	WELLSVILLE MUNI	NY
16-Dec-1996	ISP	N425EW	NYC97FA030	MACARTHUR FIELD, LONG ISL	NY
24-Dec-1996	LEB	N388LS	NYC97FA194	LEBANON	NH
21-Jan-1997	STP	N1160G	CHI97FA058	ST PAUL DOWNTOWN HOLMAN	MN
14-Feb-1997	KCVG	N922FE	NYC97LA054	CINCINNATI INTL	KY
02-Mar-1997	SLC	N117WM	SEA97FA067	SALT LAKE CITY INT'L	UT
27-Apr-1997	JYO	N885JC	NYC97FA080	LEESBURG MUNI	VA
02-Jun-1997	FWA	N171DB	CHI97LA154	FT WAYNE INTL	IN
14-Aug-1997	DNN	N74EJ	MIA97FA232	DALTON MUNI	GA
19-Sep-1997	ACK	N6879Y	NYC97LA183	NANTUCKET MEMORIAL	MA
28-Nov-1997	OYM	N6923	NYC98FA035	ST MARY'S MUNI	PA
29-Nov-1997	SPW	N22NC	CHI98LA050	SPENCER MUNI	IA
10-Dec-1997	CLT	N30SA	ATL98FA023	CHARLOTTE/DOUGLAS INTL	NC
13-Jan-1998	IAH	N627WS	FTW98MA096	G. BUSH INTERCONTINENTAL	TX
09-Feb-1998	ORD	N845AA	DCA98MA023	OHARE	IL
01-Mar-1998	PQI	N777HM	NYC98FA071	PRESQUE ISLE	ME
07-Apr-1998	BIS	N868FE	CHI98FA119	BISMARCK	ND
16-Jun-1998	HLN	N446JR	SEA98FA100	HELENA REGIONAL	MT
07-Jul-1998	PBV	N501FS	ANC98FA091	ST GEORGE	AK
17-Oct-1998		N138BA	CHI99LA008	BRAINARD MUNI	MN
28-Oct-1998		N35533	DEN99FA016	HAYDEN COLORADO	CO
03-Dec-1998	PIZ	N3542H	ANC99LA014	POINT LAY LRRS	AK
04-Dec-1998	PTK	N59902	CHI99FA047	PONTIAC/OAKLAND CO.	MI
08-Jan-1999	PDX	N141LC	SEA99FA028	PORTLAND INTL	OR
29-Jan-1999	HOT	N260LH	FTW99FA074	MEMORIAL FIELD PEARCY, AR	AR
11-Feb-1999	KSM	N31240	ANC99FA028	ANCHORAGE INT'L	AK
15-Apr-1999	KMYF	N7706R	LAX99FA150	MONTGOMERY FIELD	CA
21-Sep-1999	CCO	N27343	MIA99FA263	NEWNAN COWETA COUNTY	GA
09-Dec-1999	PLK	N525KL	CHI00FA040	M.GRAHAM PARK AIRPORT	MO
17-Jan-2000	LBL	N12654	CHI00LA058	LIBERAL MUNI	KS
21-Feb-2000	OTZ	N219CS	ANC00LA029	RALPH WEIN MEMORIAL	AK
23-Sep-2000	3B1	N590TA	NYC00LA265	GREENVILLE MUNI	ME